SCENARIO DEVELOPMENT

A REVIEW OF APPROACHES

UNEP

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ABBREVIATIONS

AIM	Asian Pacific Integrated Model
CCAFS	Climate Change, Agriculture and Food Security
CIA	Cross Impact Analysis
CGIAR	Consultative Group on International Agricultural Research
DSSAT	Decision Support System for Agrotechnology Transfer
FCM	Fuzzy Cognitive Maps
GBN	Global Business Network
GEO	Global Environment Outlook
GHG	Greenhouse Gas
GCM	Global Circulation Model
$HadCM_3$	Hadley Centre Coupled Model version 3
IAASTD	International Assessment of Agricultural Science and Technology for Development
IAM	Integrated Assessment Model
IAV	Impacts Adaptation and Vulnerability
ICONICS	International Committee on New Integrated Climate change assessment Scenarios
IFS	Interactive Future Simulation
INTERAX	Interactive Cross Impact Simulation
IMAGE	Integrated Model to Assess the Global Environment
IMPACT	Policy Analysis of Agricultural Commodities and Trade
IPCC	Intergovernmental Panel on Climate Change
IPCC SRES	IPCC Special Report on Emission Scenarios
MA	Millennium Ecosystem Assessment
OECD	Organisation for Economic Co-operation and Development
PBL	Netherlands Environmental Assessment Agency (Dutch)
RCP	Representative Concentration Pathways
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SMIC-PROB-EXPERT	Cross-Impact Matrices and Systems (French)
SSP	Shared Socioeconomic Pathways
TIA	Trend Impact Analysis
UNEP	United Nations Environment Programme
UNEP GEO	United Nations Environment Programme – Global Environment Outlook
UNEP-WCMC	United Nations Environment Programme – World Conservation Monitoring Centre


Flooding
Flood
Drought
Biodiversity
Byumba
Kinindo
Musanze
Karuzi
Bubanza
Muramvya

1. Executive Summary

This report reviews approaches to scenario development in support of policy development and decision-making based on the consideration of synergies and trade-offs between agricultural or other natural resource-based development and maintaining biodiversity and ecosystem service values. Actors working to improve food security, environmental conservation and rural livelihoods in the developing world face many uncertainties when exploring future development. Scenario development and analysis is increasingly used by scientists and policymakers to better understand potential future changes in drivers such as climate change, human population and demands for food and fuel and to address the associated uncertainties.

The review was conducted in the first instance to support UNEP-WCMC's work on assessing the potential impacts of different socioeconomic future on biodiversity and ecosystem services through land-use change. It sought to enable those who are considering using scenarios in their work to navigate the terminology, and better understand the function of scenarios, how they are used and the different scenario development approaches and methods.

The review is now being made available with a wider aim of building the capacity of national and sub-national decision makers to understand and use scenario development, in more integrated approaches to policy development and review.

Using the Intergovernmental Panel on Climate Change (IPCC) definition as a basis, this review defines scenarios as "storylines that explore plausible future states of the world or alternate states of a system". The report provides an overview of scenario users, uses and typologies, based on two main sources of data: a quasi-systematic review of literature, and a synthesis of information collected from a number of key publications cited in papers identified in the review or suggested by scenario experts. Multiple scenario typologies exist that seek to classify the large diversity of scenarios and scenario approaches and create a common understanding. Existing typologies vary in focus, from characterising the elements of a scenario development exercise, the design and methods, and the characteristics of the scenarios themselves, to using the underlying schools of thought as a means of classification.

There are a large number of terms in the literature relating to the goal, role and form of scenarios that refer to very similar concepts. As a result, there is much semantic and technical overlap, but the diverse scenario types can be broadly grouped according to their goal, role and form:

- The *goal* of scenario development can be said to be either 'exploratory' or 'anticipatory'. Exploratory scenarios are created to explore the future, given a description of the world today, an understanding of how systems interact and what changes might occur in years to come. Anticipatory scenarios often aim to provide decision support by examining paths to pre-determined futures.
- In terms of their *role* in analysis or decision-making, scenarios can either be developed as 'reference scenarios' or 'scenarios of change'. Reference scenarios describe the future in the absence of specific interventions and are commonly referred to as 'business-as-usual'. Scenarios of change, on the other hand, illustrate a future that is being shaped by a particular course of action or set of variables.
- The *form* of scenarios can be 'quantitative' or 'qualitative'. Qualitative or narrative scenarios describe possible futures primarily in a non-numerical form, often as single sentences, storylines, or diagrams. Quantitative scenarios describe possible futures primarily in a numerical form, outputting data that can be visualised as maps, graphs, or descriptive statistics. These scenarios are often developed from simulation models. In practice, scenario development often involves a combination of both forms. Quantitative models are often first developed as qualitative storylines that are then quantified in models. Both forms can be alternated and used in combination with various modelling approaches.

A large number of methods exist to support the practical application of the scenarios goal, role and form, a selection of which are summarised in this report. The choice of methods is dependent on one's objective and the role one seeks to give to scenario development and analysis. Techniques such as downscaling and linking scenarios across geographies can be important when adapting existing scenarios to different scales of analysis.

Scenario development and analysis has the potential to bring together decision makers and other stakeholders from different sectors to discuss common plausible future and their pathways. In this regard, the use of scenarios is an important tool to support objectives on increasing the understanding and consideration of synergies and trade-offs among natural resource-based development activities and environmental conservation.

1. Résumé

Le présent rapport examine les stratégies d'élaboration de scénarios à l'appui de la planification et de la prise de décision en matière de politique, en s'appuyant sur la prise en compte de synergies et de compromis entre le développement agricole ou tout autre développement axé sur les ressources naturelles et préservant les valeurs de la biodiversité et des services écosystémiques. L'élaboration et l'analyse de scénarios sont de plus en plus utilisées par les scientifiques et les décideurs politiques, d'une part, pour mieux comprendre les changements futurs plausibles de différents facteurs, tels que le changement climatique, la population humaine et les demandes de nourriture et de carburant, et, d'autre part, pour faire face aux incertitudes y afférentes. Les scénarios ajoutent de la valeur à la planification des politiques en créant une structure pour : 1) l'identification des incertitudes de l'avenir ; 2) l'intégration et les compromis ; 3) l'étude des avenirs plausibles à long terme ; 4) l'élaboration des politiques ; et 5) la description d'un avenir préétabli et des mesures nécessaires pour y parvenir. Les acteurs de tous les secteurs font face à des incertitudes lorsqu'ils explorent les options du développement à venir. Cette étude se concentre ainsi en particulier sur les acteurs œuvrant pour améliorer la sécurité alimentaire, la conservation de l'environnement et les moyens de subsistance en milieu rural dans le monde en développement.

La présente étude a été menée en premier lieu en vue de soutenir le travail du PNUE-CMSC en ce qui concerne l'évaluation des impacts plausibles de différents avenirs socioéconomiques sur les services écosystémiques et la biodiversité à travers les changements d'utilisation des terres. Il vise à permettre, à ceux qui envisagent d'avoir recours aux scénarios dans leur travail, de mieux comprendre la terminologie, la fonction des scénarios, la façon dont ils sont utilisés et les différentes stratégies et méthodes d'élaboration de scénarios. Cette étude a désormais été rendue publique. Elle a pour objectif plus large de renforcer les capacités des décideurs nationaux et infranationaux afin de comprendre et d'utiliser l'élaboration de scénarios dans le cadre de stratégies de conception et d'analyse des politiques mieux intégrées. Le présent rapport fait partie d'une série de documents, parmi lesquels des études portant sur les stratégies de cartographie de la biodiversité, des services écosystémiques et de la vocation agricole, et plusieurs modèles de changement d'utilisation des terres. Ces documents doivent être utilisés conjointement avec cette étude afin de soutenir l'intégration, à l'échelle nationale et infranationale, d'une approche de la politique et de la planification agricoles axée sur les écosystèmes. Étant donné que le rapport a pour objet l'élaboration de scénarios dans un contexte de planification agricole, il est limité dans sa portée et s'intéresse en particulier aux scénarios axés sur des modèles. De ce fait, l'interprétation des résultats doit s'inscrire dans le champ de l'étude.

Le Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC) définit les scénarios comme « une description cohérente, intrinsèquement structurée et plausible d'un état futur possible du monde. Il ne s'agit pas d'une prévision ; chaque scénario est plutôt une image possible de la façon dont l'avenir peut se dérouler. Une projection peut servir de matière première à un scénario, mais les scénarios nécessitent souvent des informations supplémentaires (p. ex., en ce qui concerne les conditions de référence). Un ensemble de scénarios est souvent adopté pour refléter au mieux l'éventail d'incertitudes dans les projections ». Le présent rapport offre un aperçu

des utilisateurs de scénarios, et des utilisations de scénarios et de typologies, en s'appuyant sur deux sources de données principales : une étude documentaire quasi systématique, ainsi qu'une synthèse des informations collectées à partir de nombreuses publications clés citées dans les documents identifiés dans l'étude ou suggérées par les spécialistes en matière de scénarios. De nombreuses typologies de scénarios existent, lesquelles cherchent à classifier la grande diversité de scénarios et de stratégies en la matière, et à faciliter une compréhension commune. L'approche des typologies existantes varie : de la caractérisation des éléments composant un exercice d'élaboration de scénarios, elle passe par la conception et les méthodes, et les caractéristiques des scénarios eux-mêmes, à l'utilisation des courants de pensée sous-jacents comme un moyen de classification.

Dans les documents, un grand nombre de termes faisant référence à l'objectif, au rôle et à la forme des scénarios renvoient à des concepts très similaires. En conséquence, il existe un important chevauchement sémantique et technique, mais les différents types de scénarios peuvent être largement regroupés en fonction de leur objectif, de leur rôle et de leur forme :

- On considère que l'élaboration de scénarios peut avoir comme *objectif* l'« exploration » ou l'« anticipation ». Les scénarios d'exploration sont créés pour étudier l'avenir à partir d'une description du monde d'aujourd'hui, d'une compréhension de la façon dont les systèmes interagissent et des changements susceptibles de survenir dans les années à venir. Les scénarios d'anticipation visent souvent à appuyer les décisions en examinant les voies menant à des avenirs prédéterminés.
- Pour ce qui est de leur *rôle* dans l'analyse ou la prise de décisions, les scénarios peuvent être élaborés en tant que « scénarios de référence ou « scénarios d'évolution ». Les scénarios de référence décrivent l'avenir en l'absence d'interventions spécifiques et sont communément désignés comme « habituels ». Les scénarios d'évolution illustrent un avenir façonné par une façon de procéder particulière ou un ensemble de variables.
- La *forme* des scénarios peut être « quantitative » ou « qualitative ». Les scénarios qualitatifs ou narratifs décrivent les avenirs possibles essentiellement sous forme non numérique, souvent au moyen de phrases simples, de canevas ou de diagrammes. Les scénarios quantitatifs décrivent des avenirs plausibles essentiellement sous forme numérique (Ramírez et Selin, 2014), produisant des données pouvant être visualisées au moyen de cartes, de graphiques ou de statistiques descriptives. Ces scénarios sont souvent élaborés à partir de modèles de simulation. En pratique, l'élaboration de scénarios implique souvent une combinaison des deux formes. Les modèles quantitatifs sont souvent élaborés en tant que canevas qualitatifs dans un premier temps, et ce, en collaboration avec les parties prenantes qui sont quantifiées dans les modèles. Il est possible d'alterner et d'utiliser les deux formes conjointement avec plusieurs approches de modélisation.

Il existe un grand nombre de méthodes pour appuyer l'application pratique de l'objectif, du rôle et de la forme des scénarios, dont certains sont résumés dans le présent rapport. Le choix des méthodes dépend de l'objectif de chacun et du rôle que l'on cherche à donner à l'élaboration et à l'analyse de scénarios. Les techniques visant à réduire et élargir l'échelle des scénarios, ainsi qu'à relier ces derniers entre eux à l'échelle de la planète, peuvent avoir une certaine importance lorsque l'on adapte les scénarios existants à différentes échelles d'analyse.

L'élaboration et l'analyse de scénarios ont le potentiel de réunir les décideurs et les parties prenantes de différents secteurs pour discuter des avenirs plausibles communs, des voies à emprunter pour y parvenir et des incertitudes les accompagnant. De cette façon, l'utilisation de scénarios est un outil important pour soutenir les objectifs visant une meilleure compréhension et prise en compte des synergies et des compromis dans les activités de développement axées sur les ressources naturelles et la conservation de l'environnement.

1. Resumen

El presente informe analiza distintos enfoques de elaboración de escenarios dirigidos a apoyar la planificación de políticas y la toma de decisiones a partir de la consideración de las sinergias y compensaciones entre los desarrollos agrícolas u otros desarrollos naturales basados en los recursos y el mantenimiento de los valores de la biodiversidad y los servicios de los ecosistemas. Tanto los científicos como los encargados de la formulación de políticas utilizan cada vez más la elaboración y los análisis de escenarios con miras a mejorar su comprensión de los posibles cambios futuros en factores como el cambio climático, la población humana y las demandas de comida y combustible, así como para abordar las incertidumbres correspondientes. Los escenarios añaden valor a la planificación de políticas mediante la creación de una estructura para 1) la identificación de incertidumbres de cara al futuro, 2) la integración y las compensaciones, 3) la exploración de futuros factibles a largo plazo, 4) la asistencia a la función normativa, y 5) la descripción de un futuro preestablecido y las acciones necesarias para lograrlo. Todos los agentes, sea cual sea su ámbito, se enfrentan a incertidumbres a la hora de explorar opciones de desarrollo futuras, si bien este informe se centra, en particular, en los actores que trabajan para mejorar la seguridad alimentaria, la conservación ambiental y los medios de vida rurales en los países en desarrollo.

El análisis se llevó a cabo, en primera instancia, para apoyar el trabajo desempeñado por el Centro Mundial de Vigilancia de la Conservación del Programa de las Naciones Unidas para el Medio Ambiente (PNUMA-WCMC) dirigido a evaluar los impactos razonables de distintos futuros socioeconómicos en la biodiversidad y los servicios de los ecosistemas a través de los cambios en el uso de la tierra. Tiene como objetivo ayudar a aquellos que estén considerando emplear diferentes escenarios en su trabajo a familiarizarse con la terminología y a mejorar su entendimiento sobre el funcionamiento de los escenarios, su utilización, y los distintos métodos y enfoques de elaboración de escenarios. El análisis se hace ahora público con el objetivo general de fomentar la capacidad de los encargados de adoptar decisiones en los ámbitos nacional y subnacional para entender y utilizar la elaboración de escenarios en el marco de unos enfoques de revisión y formulación de políticas más integrados. El informe forma parte de un conjunto de documentos, incluidos análisis de los enfoques sobre la cartografía de la biodiversidad, los servicios de los ecosistemas y la aptitud agrícola, así como varios modelos de cambio en el uso de la tierra. Estos documentos deberían utilizarse junto al presente análisis a fin de apoyar la integración de un enfoque basado en el ecosistema en la planificación y las políticas agrícolas nacionales y subnacionales. Dado que el informe se orientan al desarrollo de escenarios en un contexto de planificación agrícola, su alcance resulta limitado y se centra especialmente en los escenarios basados en modelos. Por tanto, la interpretación de los resultados debe inscribirse en el alcance de este análisis.

El Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC) define un escenario como «una descripción coherente, internamente consistente y plausible de un posible estado futuro del mundo. No se trata de una previsión, sino que cada escenario es una imagen alternativa de cómo puede desarrollarse el futuro. Una proyección puede servir como materia prima para un escenario, pero los escenarios a menudo requieren información adicional (por ejemplo sobre las condiciones de referencia). Un conjunto

de escenarios suele adoptarse con ánimo de reflejar lo mejor posible el rango de incertidumbre de las proyecciones». Este informe proporciona una perspectiva general de los usuarios, usos y tipologías de los escenarios, a partir de dos fuentes de datos principales: un análisis cuasisistemático de la bibliografía y una síntesis de la información recopilada en una serie de publicaciones clave mencionadas en los artículos identificados en el análisis o sugeridas por los expertos en materia de escenarios. Existen numerosas tipologías de escenarios que tratan de clasificar la gran diversidad de escenarios y enfoques basados en escenarios con miras a propiciar una comprensión común. Las tipologías existentes parten de distintos enfoques: desde la caracterización de los elementos de un ejercicio de elaboración de escenarios, su diseño y métodos, o de las características de los propios escenarios hasta la utilización de las corrientes de pensamiento subyacentes como método de clasificación.

Son numerosos los términos empleados en la bibliografía en relación con el objetivo, la función y la forma de los escenarios que remiten a conceptos muy similares. Por consiguiente, la superposición técnica y semántica es habitual, pero los distintos tipos de escenario pueden agruparse en líneas generales en función de su objetivo, función y forma, a saber:

- El *objetivo* de la elaboración de escenarios puede considerarse, o bien «de exploración», o bien «de anticipación». Los escenarios de exploración se crean para examinar el futuro, partiendo de una descripción del mundo actual, del conocimiento sobre cómo interactúan los sistemas y de los cambios que pueden acaecer en los años venideros. Los escenarios de anticipación a menudo tratan de servir de apoyo a la toma de decisiones mediante el análisis de las trayectorias hacia futuros predeterminados.
- En términos de su *función* en el análisis o la toma de decisiones, los escenarios pueden, o bien elaborarse como «escenarios de referencia», o bien como «escenarios de cambio». Los escenarios de referencia describen el futuro a falta de intervenciones específicas y suelen considerarse escenarios basados en el *statu quo*. Por otro lado, los escenarios de cambio ilustran un futuro conformado por una línea de acción específica o un conjunto de variables.
- La *forma* de los escenarios puede ser «cuantitativa» o «cualitativa». Los escenarios cualitativos o narrativos describen futuros posibles principalmente de una manera no numérica, a menudo con oraciones sencillas, guiones o diagramas. Los escenarios cuantitativos describen futuros verosímiles sobre todo de manera numérica (Ramírez y Selin 2014) y generan unos datos que pueden visualizarse como mapas, gráficos o estadísticas descriptivas. Estos escenarios se desarrollan con frecuencia a partir de modelos de simulación. En la práctica, la elaboración de escenarios suele combinar ambas formas. Los modelos cuantitativos suelen desarrollarse primero como guiones cualitativos, en colaboración con las partes interesadas, que posteriormente se cuantifican en los modelos. Ambas formas pueden alternarse y utilizarse en combinación con distintos enfoques de elaboración de modelos.

Los métodos que respaldan la aplicación práctica del objetivo, la función y la forma de los escenarios son muy variados; este informe presenta una selección de dichos métodos. La elección de los métodos dependerá del objetivo que se quiera alcanzar así como de la función que queramos conferir a la elaboración y el análisis de escenarios. Algunas técnicas como la reducción y ampliación de escala y la vinculación de escenarios entre distintas zonas geográficas pueden resultar convenientes a la hora de adaptar los escenarios existentes a las distintas escalas de análisis.

La elaboración y el análisis de escenarios tiene el potencial de reunir a los encargados de adoptar decisiones y los interesados de distintos sectores para debatir sobre futuros factibles comunes y sus trayectorias e incertidumbres correspondientes. En este sentido, la utilización de escenarios constituye una herramienta importante en apoyo de los objetivos relacionados con la mejora del conocimiento y la consideración de las sinergias y compensaciones entre las actividades de desarrollo basado en los recursos naturales y la conservación ambiental.

1. Sumário Executivo

O presente relatório analisa abordagens para desenvolvimento de cenários em apoio do planeamento da política e de tomada de decisão com base na consideração de sinergias e compensações entre desenvolvimento baseado em recursos naturais agrícola ou outro e manter a biodiversidade e os serviços ecossistêmicos. desenvolvimento de cenários e análise é cada vez mais utilizado por cientistas e decisores políticos a compreender melhor plausíveis mudanças futuras na motoristas como as alterações climáticas, população humana e as demandas por alimentos e combustíveis e para tratar as incertezas associadas. Cenários de agregar valor ao planejamento de políticas através da criação de uma estrutura para 1) incerteza futura, 2) integração e trade-offs, 3) explorar futuros plausíveis de longo prazo, 4) auxiliando a formulação de políticas, e 5) descrevendo um futuro pré-especificado e as ações necessárias para alcançá-lo. Atores em todos os campos enfrentam incertezas ao explorar futuras opções de desenvolvimento, esta revisão centra-se especificamente sobre os atores que trabalham para melhorar a segurança alimentar, a conservação ambiental e meios de subsistência rurais no mundo em desenvolvimento.

A revisão foi conduzida em primeira instância, para apoiar o trabalho do United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) em avaliar os impactos plausíveis de diferentes futuros socioeconômicos sobre biodiversidade e serviços ambientais através da mudança do uso da terra. Destina-se a permitir que aqueles que estão pensando em usar cenários em seu trabalho para navegar a terminologia, a entender melhor a função de cenários, como eles são usados e as diferentes abordagens e métodos de desenvolvimento de cenário. A revisão está sendo feito agora disponível com um objetivo mais amplo de construir a capacidade dos decisores nacionais e sub-nacionais para entender e usar o desenvolvimento cenário em abordagens mais integradas no desenvolvimento de políticas e avaliação. O relatório faz parte de um conjunto de documentos, incluindo avaliações de abordagens para a biodiversidade mapeamento, serviços ecossistémicos e aptidão agrícola, e modelos de mudança de uso da terra. Estes devem ser usados em conjunto com este comentário para apoiar a integração de uma abordagem ecossistémica à política agrícola e planejamento em nível nacional e sub-nacional. Como o relatório visa a elaboração de cenários em um contexto de planejamento agrícola, é limitada em seu alcance com um foco particular em cenários baseados em modelos. Como tal, os resultados devem ser interpretados dentro do âmbito da avaliação.

O Painel Intergovernamental sobre Mudanças Climáticas (IPCC) define cenários como "uma descrição coerente, internamente consistente e plausível de um possível estado futuro do mundo. Não é uma previsão; em vez disso, cada cenário é uma imagem alternativa de como o futuro pode se desdobrar. A projeção pode servir como matéria-prima para um cenário, mas cenários muitas vezes exigem informações adicionais (por exemplo, sobre as condições da linha de base). . Um conjunto de cenários é frequentemente adoptada para refletir, tão bem quanto possível, o intervalo de incerteza nas projeções "Este relatório fornece uma visão geral dos usuários cenário, a utilização de cenários e tipologias, com base em duas fontes principais de dados: um quase-sistemática revisão da literatura e uma síntese da informação recolhida a partir de um número de publicações importantes mencionadas nos documentos identificados na revisão ou sugeridas por especialistas de cenário. Existem várias tipologias de cenários que procuram classificar a grande diversidade de cenários e abordagens de cenários e criar um entendimento comum. tipologias existentes variam em foco; de caracterizar os elementos de um exercício de desenvolvimento cenário, o desenho e métodos, as características dos próprios cenários, a usar as escolas subjacentes de pensamento como meio de classificação.

Há um grande número de termos na literatura relativos à meta, o papel e forma de cenários que se referem a conceitos muito semelhantes. Como resultado, há muita sobreposição semântica e técnica, mas os diversos tipos de cenários podem ser agrupadas de acordo com seu objetivo, papel e forma:

- O *objetivo* de desenvolvimento de cenários pode ser dito para ser 'exploratória' ou 'antecipação'. cenários exploratórios são criadas para explorar o futuro, dada uma descrição do mundo de hoje, uma compreensão de como os sistemas interagem e que mudanças podem ocorrer nos próximos anos. cenários de antecipação muitas vezes como objectivo proporcionar apoio à decisão ao examinar caminhos pré-determinados futuros.
- Em termos de seu *papel* na análise e tomada de decisões, os cenários podem ser desenvolvidos como 'cenários de referência "ou" cenários de mudança'. cenários de referência descrever o futuro na ausência de intervenções específicas e são comumente referido como "business-as-usual". Cenários de mudança, por outro lado ilustram um futuro que está sendo moldada por um determinado curso de ação ou conjunto de variáveis.
- A *forma* de cenários pode ser 'quantitativa' ou 'qualitativa'. cenários qualitativos ou narrativas descrevem possíveis futuros, principalmente, numa forma não-numérica, muitas vezes como uma única sentença, histórias, ou diagramas. cenários quantitativos descrevem futuros plausíveis, principalmente, numa forma numérica (Ramírez & Selin 2014), saída de dados que pode ser visualizado como mapas, gráficos ou estatística descritiva. Estes cenários são muitas vezes desenvolvidos a partir de modelos de simulação. No desenvolvimento cenário prática muitas vezes envolve uma combinação de ambas as formas. modelos quantitativos são muitas vezes primeiro desenvolvido como storylines qualitativos, em colaboração com as partes interessadas, que são então quantificados em modelos. Ambas as formas podem ser alternados e usado em combinação com diversas abordagens de modelagem.

Um grande número de métodos existem para apoiar a aplicação prática da meta cenários, papel e forma, uma seleção dos quais estão resumidos neste relatório. A escolha dos métodos depende de sua objetiva e o papel se procura dar para o desenvolvimento e análise de cenários. Técnicas como a redução de escala e upscaling e ligando cenários em todas as geografias pode ser importante quando adaptando cenários existentes para diferentes escalas de análise.

desenvolvimento de cenários e análise tem o potencial de reunir decisores e intervenientes de diferentes setores para discutir futuros plausíveis comuns e suas vias e incertezas. A este respeito, o uso de cenários é uma ferramenta importante para apoiar os objectivos de aumentar a compreensão e consideração das sinergias e trade-offs entre as actividades de desenvolvimento baseadas em recursos naturais e conservação ambiental.

1. Резюме

В этом докладе содержится обзор подходов к разработке сценариев в поддержку планирования политики и принятия решений на основе рассмотрения синергизма и компромиссов между сельскохозяйственным и иным природным ресурсом на основе развития и поддержания биоразнообразия и экосистемных услуг ценностей. разработка и анализ сценариев все чаще используется учеными и политиками, чтобы лучше понять вероятные будущие изменения таких факторов, как изменение климата, популяции человека и требует для производства продовольствия и топлива, а для решения связанных с этим неопределенностей. Сценарии добавить значение планирования политики путем создания структуры для 1) будущей неопределенности, 2) интеграция и компромиссы, 3) изучение долгосрочных правдоподобные фьючерсов, 4) пособничество выработку политики, и 5), описывающие предопределенный будущее и действия, необходимые для достижения этой цели. Актеры во всех областях сталкиваются с неопределенностью при изучении будущих вариантов развития, в этом обзоре особое внимание уделяется актеров, работающих в сфере повышения уровня продовольственной безопасности, охраны окружающей среды и жизни в сельских районах в развивающихся странах.

Обзор был проведен в первую очередь, чтобы поддержать работу Программа Организации Объединенных Наций по окружающей среде Всемирного центра природоохранного мониторинга (UNEP-WCMC) по оценке вероятных последствий различных социально-экономических фьючерсов на биоразнообразия и экосистемных услуг за счет изменений в землепользовании. Она призвана помочь тем, кто рассматривает возможность использования сценариев в своей работе ориентироваться в терминологии, лучше понять функции сценариев, как они используются и различные подходы и методы разработки сценариев. Обзор в настоящее время доступны с более широкой целью укрепления потенциала национальных и субнациональных лиц, принимающих решения, чтобы понять и использовать разработку сценариев в более комплексных подходов к разработке политики и обзора. Отчет является частью пакета документов, в том числе обзоров подходов к биоразнообразию картирования, экосистемных услуг и сельского хозяйства, а также пригодности моделей изменения землепользования. Они должны использоваться в сочетании с этого обзора для поддержки интеграции экосистемного подхода на основе к сельскохозяйственной политики и планирования на национальном и субнациональном уровнях. Как отмечается в докладе направлен на разработку сценария в контексте планирования сельского хозяйства, она ограничена по своим масштабам с особым акцентом на основе моделей сценариев. Таким образом, результаты должны интерпретироваться в пределах объема обзора.

Межправительственная группа экспертов по изменению климата (МГЭИК) определяет сценарии как “единое, внутренне последовательной и убедительной описания возможного будущего состояния мира. Это не прогноз; скорее, каждый сценарий один альтернативный образ того, как в будущем может разворачиваться. Выступ может служить в качестве сырья для сценария, но сценарии часто требуют дополнительной информации (например, о базовых условиях). . Набор сценариев часто принимается для отражения, а также по возможности, диапазон неопределенности в прогнозах “В настоящем докладе содержится обзор пользователей

сценариев, использования сценариев и типологий, исходя из двух основных источников данных: квази-систематический характер обзор литературы и обобщение информации, собранной из ряда ключевых публикаций, указанных в документах, указанных в обзоре или предложенных экспертами сценариев. Несколько типологий сценариев существуют, которые стремятся классифицировать большое разнообразие сценариев и подходов сценариев и создать общее понимание. Существующие типологий различаются в центре внимания; от характеризующие элементы упражнений сценарий развития, дизайн и методы, характеристики сценариев себя, используя основные школы мысли как средство классификации.

Есть большое количество терминов в литературе, относящихся к цели, роли и формы сценариев, которые ссылаются на очень схожие понятия. В результате, существует много семантическая и техническое перекрытие, но различные типы сценариев могут быть широко сгруппированы в соответствии с их цели, роли и формы:

- Целью разработки сценариев можно сказать либо “исследовательское” или “упреждающий”. Пробные сценарии созданы, чтобы исследовать будущее, дано описание современного мира, понимание того, как системы взаимодействуют и какие изменения могут произойти в ближайшие годы. Упреждающие сценарии часто нацелены на обеспечение поддержки принятия решений путем изучения путей к предопределены фьючерсов.
- С точки зрения их роли в анализе или принятия решений, сценарии могут быть либо разработаны в качестве «эталонных сценариев» или «сценарии изменения». Эталонные сценарии описывают будущее в отсутствие конкретных мер и обычно упоминаются как «бизнес как обычно». Сценарии изменения с другой стороны иллюстрируют будущее, которое формируется с помощью определенного курса действий или набора переменных.
- Форма сценариев может быть «количественный» или «качественный». Качественные или сюжетные сценарии описывают возможные варианты будущего в первую очередь в нечисловым форме, часто в виде отдельных фраз, сюжетные линии, или диаграммы. Количественные сценарии описывают вероятные события в будущем, прежде всего, в числовой форме (Ramírez & Selin 2014), вывода данных, которые можно представить в виде карт, графиков или описательной статистики. Эти сценарии часто разрабатываются из имитационных моделей. В разработке сценария практике часто включает в себя сочетание обеих форм. Количественные модели часто впервые разработаны как качественные сюжетные линии, в сотрудничестве с заинтересованными сторонами, которые затем количественно в моделях. Обе формы можно чередовать и использовать в сочетании с различными методами моделирования.

Большое количество методов существуют для поддержки практического применения сценариев цели, роли и формы, выбор которых кратко изложены в настоящем докладе. Выбор методов зависит от одной-х цель и роль один стремится придать развитию и анализу сценариев. Такие методы, как и экстраполяция разукрупнение и компоновки сценариев из разных регионов могут иметь важное значение при адаптации существующих сценариев к различным шкалам анализа.

разработка и анализ сценариев имеет потенциал для объединения лиц, принимающих решения, и заинтересованных сторон из различных секторов для обсуждения общих правдоподобные фьючерсных и их пути и неопределенности. В связи с этим, использование сценариев является важным инструментом для поддержки целей по повышению понимания и учета синергизма и компромиссов между природными ресурсами деятельности в области развития на основе и охраны окружающей среды.

وهناك عدد كبير من المصطلحات في الأدب المتعلقة هدف ودور وشكل من السيناريوهات التي تشير إلى مفاهيم مماثلة جدا. ونتيجة لذلك، هناك الكثير من التداخل الدلالي والفني، ولكن أنواع السيناريو متنوعة يمكن تصنيفها على نطاق واسع وفقا لهدفهم ودور وشكل:

- إن الهدف من وضع السيناريوهات يمكن أن يقال أن تكون إما "الاستكشافية" أو "استباقي". يتم إنشاء سيناريوهات استطلاعية لاستكشاف المستقبل، نظرا لوصف العالم اليوم، وفهم كيفية تفاعل أنظمة وما قد يحدث تغييرات في السنوات المقبلة. غالبا ما تهدف السيناريوهات الاستباقية لتوفير دعم اتخاذ القرار من خلال دراسة مسارات محددة سلفا الآجلة.

- من حيث دورها في تحليل أو اتخاذ القرارات، ويمكن أن تكون إما وضعت سيناريوهات باسم 'السيناريوهات المرجعية "أو" سيناريوهات التغيير". تصف السيناريوهات المرجعية المستقبل في حالة عدم وجود تدخلات محددة ويشار عادة باسم "العمل كالمعتاد". سيناريوهات التغيير من ناحية أخرى توضح مستقبل الذي يتم على شكل من مسار عمل معين أو مجموعة من المتغيرات.

- شكل من سيناريوهات يمكن أن يكون "الكمي" أو "النوعي". سيناريوهات النوعية أو سردية تصف العقود الآجلة المحتملة في المقام الأول في شكل غير العددي، وغالبا ما جمل واحد، الوقائع المنظورة، أو الرسوم البيانية. سيناريوهات الكمية تصف العقود الآجلة معقولة في المقام الأول في شكل رقمي (Ramírez & Selin 2014)، إخراج البيانات التي يمكن تخيلها على الخرائط والرسوم البيانية، أو الإحصاء الوصفي. وغالبا ما وضعت هذه السيناريوهات من نماذج المحاكاة. في وضع السيناريوهات ممارسة غالبا ما ينطوي على مزيج من هذين النوعين. وغالبا ما وضعت النماذج الكمية أولا كما الوقائع المنظورة النوعية، بالتعاون مع أصحاب المصلحة، أن يتم بعد ذلك كميا في النماذج. كلا الشكلين يمكن تناوبت واستخدامها في تركيبة مع النهج النمذجة المختلفة.

وهناك عدد كبير من الطرق لدعم التطبيق العملي للهدف السيناريوهات ودورها وشكل، ومجموعة مختارة من التي تتلخص في هذا التقرير. اختيار أساليب تعتمد على واحد هدف ودور واحد يسعى إلى إعطاء لوضع السيناريوهات وتحليلها. تقنيات مثل تقليص حجم والنهوض بها وربط السيناريوهات في مناطق جغرافية يمكن أن تكون هامة عند التكيف مع السيناريوهات القائمة على مستويات مختلفة من التحليل.

وضع السيناريوهات وتحليل لديها القدرة على الجمع بين صناع القرار وأصحاب المصلحة من مختلف القطاعات لمناقشة العقود الآجلة المعقولة المشتركة وممراتها والشكوك. في هذا الصدد، واستخدام سيناريوهات أداة هامة لدعم أهداف على زيادة الفهم والنظر في أوجه التآزر والمقايضات بين أنشطة التنمية الطبيعية القائمة على الموارد والحفاظ على البيئة.

1. ملخص تنفيذي

يستعرض هذا التقرير النهج لتطوير السيناريو دعما للتخطيط السياسات واتخاذ القرارات على أساس النظر في أوجه التآزر والمقايضات بين التنمية القائمة على الموارد الطبيعية الزراعية وغيرها، والحفاظ على التنوع البيولوجي وخدمات النظم الإيكولوجية القيم. يستخدم وضع السيناريوهات وتحليلها على نحو متزايد من قبل العلماء وصانعي السياسات على فهم أفضل للتغيرات المستقبلية الممكنة في برامج تشغيل مثل تغير المناخ، والسكان، ويتطلب الغذاء والوقود والتصدي لحالات عدم اليقين المرتبطة بها. سيناريوهات تضيف قيمة لتخطيط السياسات عن طريق إنشاء هيكل لل1) عدم اليقين في المستقبل، 2) التكامل والمقايضات، 3) استكشاف العقود الآجلة معقولة على المدى الطويل، 4) المساعدة صنع السياسات، و5) واصفا مستقبل محدد من قبل والإجراءات اللازمة لتحقيق ذلك. الجهات الفاعلة في كافة المجالات تواجه الشكوك عند دراسة الخيارات التطويرية المستقبلية، هذا الاستعراض يركز تحديدا على الجهات الفاعلة التي تعمل على تحسين الأمن الغذائي والمحافظة على البيئة وسبل العيش الريفية في العالم النامي.

وقد أجريت المراجعة في المقام الأول لدعم عمل United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) على تقييم الآثار معقولة العقود الآجلة الاجتماعية والاقتصادية المختلفة في مجال التنوع البيولوجي وخدمات النظم الإيكولوجية من خلال التغير في استخدام الأراضي. ويهدف البرنامج إلى تمكين أولئك الذين يفكرون باستخدام سيناريوهات في عملهم للتنقل المصطلحات، فهم وظيفة من السيناريوهات، كيفية استخدامها والمناهج وطرق وضع السيناريوهات المختلفة بشكل أفضل. ويجري حاليا بذل استعراض المتاحة مع هدف أوسع لبناء قدرات صانعي القرار الوطني ودون الوطني على فهم واستخدام وضع السيناريوهات في نهج أكثر تكاملا في وضع السياسات والمراجعة. ويشكل التقرير جزءا من مجموعة من الوثائق، بما في ذلك استعراض لنهج التنوع البيولوجي رسم الخرائط، وخدمات النظام الإيكولوجي وملاءمة الزراعية، ونماذج التغير في استخدام الأراضي. هذه ينبغي أن تستخدم جنبا إلى جنب مع هذا الاستعراض لدعم دمج نهج قائم على النظام الإيكولوجي في السياسة الزراعية والتخطيط على المستويين الوطني ودون الوطني. كما يهدف هذا التقرير في وضع السيناريوهات في سياق التخطيط الزراعي، هي محدودة في نطاقها، مع التركيز بشكل خاص على السيناريوهات القائمة على النموذج. على هذا النحو، ينبغي تفسير النتائج ضمن نطاق الاستعراض.

يعرف الفريق الحكومي الدولي المعني بتغير المناخ (IPCC) سيناريوهات بأنه "وصف متماسك ومتسق داخليا والمعقول من الممكن اقامة دولتهم في المستقبل من العالم. وهي ليست التنبؤ؛ بدلا من ذلك، كل السيناريو هو صورة واحدة بديلة لكيفية المستقبل يمكن أن تتكشف. إسقاط يمكن أن تستخدم كمادة أولية لهذا السيناريو، ولكن غالبا ما تتطلب سيناريوهات معلومات إضافية (على سبيل المثال حول ظروف خط الأساس). . وهناك مجموعة من السيناريوهات غالبا ما اعتمد لتعكس، وكذلك ممكن، ومجموعة من عدم اليقين في إسقاطات "يقدم هذا التقرير لمحة عامة عن المستخدمين السيناريو، يستخدم من السيناريوهات والأنماط، استنادا الى اثنين من المصادر الرئيسية للبيانات: شبه منهجي مراجعة الأدب، وتجميع المعلومات التي تم جمعها من عدد من المنشورات الرئيسية التي ورد ذكرها في الأوراق المحددة في استعراض أو اقترحت من قبل خبراء السيناريو. توجد الأنماط السيناريو المتعددة التي تسعى لتصنيف التنوع كبير من السيناريوهات والنهج السيناريو وخلق فهم مشترك. تختلف الأنماط الموجودة في التركيز؛ من تميز عناصر من عملية وضع السيناريوهات، وتصميم وأساليب، وخصائص السيناريوهات أنفسهم، لاستخدام المدارس الكامنة وراء الفكر كوسيلة للتصنيف.

1. 执行摘要

本报告评论接近方案制定，以支持政策规划和基础上，考虑农业或其他基于自然资源的开发和维护生物多样性和生态系统服务价值之间的协同作用和权衡的决策。方案开发和分析越来越多地被科学家和决策者更好地了解未来的驱动程序，如气候变化，人口可能出现的变化以及粮食和燃料需求，并解决相关的不确定性。方案由 1）未来的不确定性产生的结构增加价值的政策规划，2）整合和取舍，3）探索长期可能的未来，4）协助政策制定，以及，5）描述预先确定的未来和需要采取的行动实现它。探索未来发展的选择，当在各个领域的行动者面临的不确定性，这种审查特别侧重于工作，改善粮食安全，环境保护和农村生活在发展中世界的演员。

该审查一审进行支持通过土地利用变化评估不同的社会经济期货对生物多样性和生态系统服务的合理撞击 United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)的工作。它的目的是使那些谁使用场景在工作中导航的术语考虑，更好地理解的情况下，他们是如何使用和不同的情景开发的途径和方法的功能。审查目前正在提供与建设国家和地方决策者的理解和更综合的方法来制定政策和审查使用场景开发的能力，更广泛的目标。该报告形成一套文件，包括方案审查，以映射生物多样性，生态系统服务和农业的适宜性，和土地利用变化模型的一部分。这些应该结合使用，这种审查，以支持基于生态系统的方法，农业政策和规划的整合在国家和地方层面。由于该报告是在农业规划背景下，旨在开发方案，在其范围限于特别注重基于模型的场景。这样，其结果应审查的范围内进行解释。

在政府间气候变化专门委员会（IPCC）的情况定义为“世界未来可能状态的连贯，一致且可信的描述。它不是一个预测;相反，每一个情景是未来可以怎样展开一个选择的图像。的投影可作为原料的情形，但场景常常需要额外的信息（例如关于基线条件下）。。一组场景通常采用反映，以及可能的，在预测的不确定性范围“这份报告提供了方案的用户的概述，使用场景和类型，基于数据主要有两个来源：一个准系统文献回顾，并从一些在审查中发现或建议的方案专家论文被引用重点出版物收集的信息进行了汇总。多场景类型学存在，寻求的场景和情景办法的大型多元化分类，并建立一个共同的理解。现有的类型学焦点各不相同;从表征场景开发工作的元件，设计和方法，该方案的特征本身，使用的思想的根本学校作为分类的手段。

有引用非常相似的概念的大量有关的场景的目标，作用和形式在文献术语。其结果是，有很多的语义和技术重叠，但不同的场景类型，大致可分为根据其目的，作用和形式：

- 情景发展的目标，可以说是’试探’或’预期’。探索场景的设置是为了开拓未来，给世界的描述的今天，如何系统交互的理解和来可能发生的变化什么年。预期的情况往往旨在通过检查路径预先确定期货提供决策支持。
- 在他们的分析或决策中的作用而言，方案可以被开发为“参考情景”或“变化的场景”。参考情景描述未来在没有具体的干预措施，并通常被称为“业务照常”。变化在另一方面的情况下示出了未来正在由行动的特定课程形或设置的变量。
- 的情景的形式可以是“定量”或“质”。定性或叙事场景描述可能的未来主要是在一个非数字的形式，通常为单句，故事情节，或图表。定量描述的场景可能的未来主要以数字形式（Ramírez & Selin 2014），输出可以作为可视化地图，图表或描述性统计数据。这些方案通常是由仿真模型开发。在实践中情景开发常常涉及的这两种形式的组合。量化模型往往首先开发定性的故事情节，在合作与利益相关方，即然后在模型量化。这两种形式可以交替并与各种建模方法结合使用。

大量的方法可用来支持的场景的目标，作用和形式，可以选择其中的总结在本报告中的实际应用。方法的选择依赖于一个人的目标和一个旨在使方案开发和分析中的作用。调整现有情景分析的不同尺度时技术，如降尺度和升频和跨地域连接的情况也很重要。

方案开发和分析具有汇集决策者和利益相关者来自不同界别，讨论共同可能的未来和他们的途径和不确定性的潜力。在这方面，使用情景是支持在增加之中自然资源为基础的开发活动和环境保护的协同作用和权衡的认识和考虑目标的重要工具。

2. Introduction

Over the coming decades, society will have to balance competing needs for land to feed the growing population, to provide resources and energy to satisfy the ever-accelerating human consumption, to slow global warming and to reduce the rate of loss of ecosystem services and biodiversity. Decision makers need to balance these different demands on land and evaluate potential trade-offs, and evaluate how they will change in the future.

Researchers, policymakers, entrepreneurs and development practitioners, working to improve food security, environmental conservation and rural livelihoods in the developing world, face many uncertainties and challenges when exploring future development (Ericksen *et al.* 2009). It is difficult to predict what economic, political and social conditions will be like in the next few years, and virtually impossible to predict the medium to longer term (Van Vuuren *et al.* 2012), especially when taking into account the likely effects of future climate change and variability. In addition, different stakeholders can have different understandings of the challenges, desired actions, outcomes and opportunities and objectives may also be in conflict as a result of e.g. power differences.

To date, most scenario development and analysis has been developed in the private sector and the military (Wilkinson & Krupers 2015; Wilkinson & Ramírez 2010), however, scenario work is increasingly being used by scientists and policymakers to better understand potential future changes in drivers such as climate change, human population and demands for food and fuel, and to address the associated uncertainties. Scenarios support increased understanding of the plausible future implications of current trends (e.g. Tedesco & Fettweis 2012), to help inform sustainable management strategies (e.g. Worrapimphong *et al.* 2010), to support flexible long-term planning, and to test the impact of interventions (e.g. Shrestha *et al.* 2012).

Scenarios offer a way to address uncertainty about the future by creating "coherent, internally consistent storylines that explore plausible future states of the world or alternate states of a system" (adapted from IPCC 2013). Rather than trying to predict one future, a diverse and contrasting set of scenarios can be used to explore future uncertainty. Even though any single scenario is extremely unlikely to happen, a set of different scenarios can help explore plausible futures – rather than trying to predict one future. The development and analysis of such scenarios provide an extremely powerful tool to help inform environmental, economic and development-related decisions.

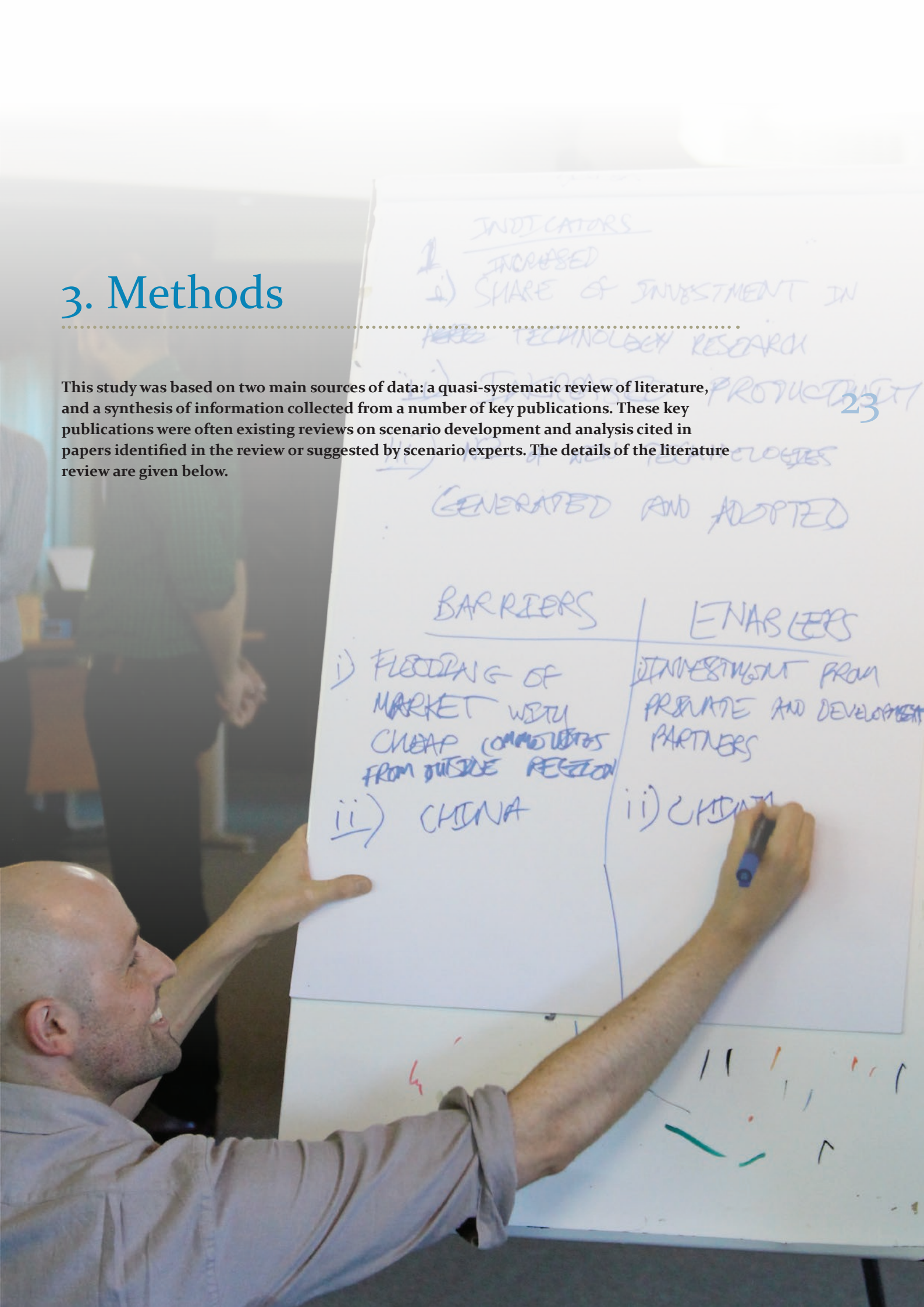
Using scenarios as a tool to explore plausible futures and support decision-making is called scenario analysis or scenario planning. Other terms related to scenario development, analysis and planning used in the literature include projections, pathways, transitions, visioning and horizon scanning. They are part of the fields of strategic foresight and future studies. Many of these relate to approaches that make use of scenarios to support improved decision-making in the context of future socioeconomic and environmental uncertainties.

In order for scenarios to be successful in guiding decision-making, it is important they are inclusive, credible and legitimate with ownership and capacity of implementation based at the home organisations of decision makers (Vervoort *et al.* 2014). It is also important that the uptake and impact of different scenarios on land use planning is assessed to avoid perpetuating bad, ineffective and non-inclusive scenario practice. This review presents different scenario types and methodologies but the impact of these different scenarios on decision-making is not assessed as part of this review.

This report seeks to synthesise and provide an overview of the large amount of peer-reviewed material published on scenarios to enable those who are considering using scenarios in their work to navigate the terminology, better understand the function of scenarios, how they are used and the different scenario development approaches and methods. The review was compiled in 2014 to support UNEP-WCMC's work on assessing the potential impacts of different socioeconomic futures on biodiversity and ecosystem services through land-use change. The review is one of six technical review studies conducted as part of UNEP-WCMC's "*Commodities and Biodiversity*" project, funded by the John D. and Catherine T. MacArthur foundation. The report has since been revised with the aim of building the capacity of national and sub-national decision makers to understand and use scenario development in more integrated approaches to policy development and review. The results will form part of an online learning tool which aims to familiarise decision makers with the different methodologies available, an approach that has been recommended by Vervoort *et al.* (2010).

3. Methods

This study was based on two main sources of data: a quasi-systematic review of literature, and a synthesis of information collected from a number of key publications. These key publications were often existing reviews on scenario development and analysis cited in papers identified in the review or suggested by scenario experts. The details of the literature review are given below.



3.1. QUASI-SYSTEMATIC LITERATURE REVIEW

Literature and search terms

In March 2014, two online databases of peer reviewed articles, SciVerse's Scopus and ISI's Web of Science, were queried with an equivalent search term. A simple search term was created using three key words: "scenario", "local" and "global". Using global or local increased the relevance of the search results by removing literature that used the word "scenario" in a different context to that used in this report. Given the scope of this review, it was felt appropriate to further limit the research areas analysed to just literature that is environmental (further details in Appendix 1).

By restricting the search to 'scenarios', it is possible that papers on related concepts were missed. For example, other terms that could have been included are: visions, projections, pathways, transitions, strategies, future studies, foresight and horizon scanning. In addition, by restricting the search to published literature, scenario studies using the IPCC-guided scenarios would have been underrepresented. However, owing to time and resources, it was decided that such restriction was necessary.

Selection of papers for review

The search terms resulted in a combined total of 36,240 papers from Scopus and Web of Science. Following the removal of duplicate records, a total of 18,547 unique articles remained. These papers then went through a number of selection rounds (details in Appendix 1). First, articles were removed if their titles did not mention scenarios in some capacity, either directly or indirectly through the topic covered. Then, remaining articles whose abstracts did not mention scenarios specifically, either directly or indirectly through the description of the paper's objectives, were excluded. Given that a paper could still include valuable information even if it did not meet the selection criteria above, a precautionary approach was taken. Out of 2,112 resulting papers 116 were selected (list in Appendix 1). This was a largely subjective process based on papers that were of most relevance to the scenarios work at UNEP-WCMC and recommendations from experts at the CGIAR research program on Climate Change, Agriculture and Food Security (CCAFS) with whom UNEP-WCMC has worked on developing scenarios under the "*Commodities and Biodiversity*" project.

The results of the literature review are presented as a descriptive synthesis of how the literature describes scenarios, their purpose, and how they are built and used. Case studies are highlighted to provide examples of scenario development and application. Word clouds, which display the relative frequency of each keyword, are used to illustrate the subject areas most frequently mentioned in the papers resulting from the quasi-systematic review process.

4. Results

4.1. SCENARIO USERS

Two broad groups of users were identified from the literature review.

Scientists

The most common usage of scenarios reported in the reviewed articles was in studies that sought to describe how a particular system or area may plausibly develop in the future. The vast majority of scenarios used for this purpose were quantitative in nature and made use of complex modelling procedures to explore the future. The level of detail included in these articles was often very high and tended to focus on the technical creation, justification and testing of a scenario or model. It should be noted though that since the systematic literature review was based on scientific search engines, most scenario results are also used by scientists. Inclusion of 'grey' literature, where a large portion of scenarios work is published, would likely indicate a broader scenario development and user base.

Decision makers

A large number of articles describe the development of scenarios by scientists which are intended to support decision-making at different levels, including for policy-making and business strategy development. This included articles where scenarios are used to:

- Describe the broad area in which a solution to a particular problem can be found
- Examine the consequences and the effectiveness of various policy approaches, or to investigate the broad type of policy response that would be necessary in order to achieve a particular goal
- Investigate ways to respond to unexpected events that affect markets and business opportunities
- Provide a basis for decision support tools

While the review did not specifically focus on the actual implementation and impact of the use of scenarios in decision-making some additional articles were included to review the impacts of scenario development on policy-making, up to 2016 (see section 4.9: Scenarios and decision-making).

The process of creating scenarios can also be part of a management strategy whereby scenarios are generated through engaging with local stakeholders and then used to investigate, with them, the wider impacts of their actions and to influence people's decisions (Worrapimphong *et al.* 2010).

4.2. AREAS OF FOCUS

In the 116 articles resulting from the quasi-systematic review, climate change was the most frequently occuring focus area for the use of scenarios in the environmental sector. Figure 1 illustrates this with a word cloud where the font size is proportional to the frequency of occurrence of the key word in all 116 papers. In addition to climate change, policy impacts, water resources, land-use change and carbon emissions were also all subject areas in which scenarios were used quite extensively.

Figure 1: Word cloud of the subject areas to which scenarios were applied in the reviewed articles.

4.3. USES OF SCENARIOS

Scenarios allow audiences to learn and think about plausible futures, and about the signposts en route to these futures, enabling them to better manage long-term risks and proactively seize emerging opportunities. Depending on the process used, scenarios can also challenge the assumptions that people have about the future and can illustrate the different views held by participants of a scenario-building exercise.

From the literature reviewed, a number of broad uses of scenario development and analysis were identified. They include a mixture of qualitative and quantitative scenario approaches which are used:

- To define the broad context within which a plausible future might lie
- To provide inputs to models, in order to create further scenarios of particular systems of interest
- To generate a range of possible ways to deal with a particular problem and investigate the potential contribution these solutions could offer
- To investigate the impacts associated with a particular course of action, or as a consequence of a particular trend that has been observed
- To educate a particular audience about a plausible future through building a scenario with their input as the drivers of the model
- To test a model by helping to identify which of its components need attention
- To test the robustness of current plans/policies
- As part of a sensitivity analysis

As part of the process of data collection the particular scenario used or created was noted where provided. Figure 2 shows the most commonly used scenarios at the time of this review in 2014, with a word cloud where the font size is proportional to the frequency of occurrence of the scenario name. The scenarios most commonly used were IPCC SRES (A2 and B1). For more detail on IPCC scenarios see Appendix 2). The newer IPCC RCP and associated SSP scenarios have not been around long enough to be reflected in this result but are more common in recent scenario literature than the SRES scenarios.

Figure 2: Word cloud representing the frequency of occurrence of particular scenarios in the reviewed articles.

4.4. SCENARIO TYPES AND CHARACTERISTICS

This section seeks to illustrate diverse scenario types whilst considering their practical application. It should be emphasised that scenario types should not be considered mutually exclusive and that there are a large number of terms used in the literature to refer to very similar concepts. The terms used are open to interpretation and relate to the level of scenario philosophy one wishes to take into consideration (see Section 4.5.). As a result, there is a large degree of semantic and technical overlap. The scenario types presented in this section are grouped according to their goal, their role and their form.

The goal of the scenario analysis

The first way in which scenarios are commonly grouped is by the goal of the scenario analysis. While overlap is possible, at the broadest level the goal of scenarios can be said to be either 'exploratory' or 'anticipatory' (see van Notten *et al.* 2003).

Exploratory scenarios

Exploratory scenarios are created to explore the future, given a description of the world today, an understanding of how systems interact and what changes might occur in years to come. They are used to explore the relationship between different systems and what the consequences of changes might be, for example the range of plausible effects that climate change could have on the availability of water resources (Box 1) or on forest ecosystems (Box 2). This scenario type therefore begins conceptually in the present, without a strong preconception of the future. The goal might include awareness raising, the stimulation of creative thinking or gaining insight into the way particular processes influence one another (van Notten *et al.* 2003). In exploratory scenario exercises the process is often as important as the final product.

Box 1: Assessing the impact of climate change on water supply and flood hazard in Ireland

This study estimates the changes in effective runoff for the island of Ireland under different climate change scenarios.

The output from the $HadCM_3$ Global Climate Model is downscaled using statistical techniques to provide precipitation and evaporation data, which is then used to drive a rainfall-runoff model. Simulations are carried out for the baseline period and two future scenarios.

The results indicate spatial variation in decreases and increases in annual runoff, with implications for water availability and flood frequency and timing. In combination with spatially explicit socio-economic information (e.g. population density), such scenario analysis can help understand what the wider consequences of these changes might be.

(Charlton *et al.* 2006)

Box 2: Nitrogen dynamics of a mountain forest on dolomitic limestone – a scenario-based risk assessment

The forests found on the dolomitic bedrock in the Austrian Alps are considered highly sensitive to expected environmental changes, which has prompted an investigation into the plausible impacts of future climate change.

Three sets of scenarios were investigated, these being the current climate, the current nitrogen deposition and future climate (+2.5°C and +10 percent annual precipitation), with three levels of nitrogen deposition. These scenarios, in conjunction with the outputs from a small-scale climate model, were used to provide the two models used in this project with the inputs required to calculate the projected impact on soil hydrology and nitrate leaching, and subsequent change in forest ecosystems due to the changes in climate and nitrogen availability.

(Jandl *et al.* 2008)

Scenarios used for exploratory purposes are also used for exploring relatively unknown areas (Box 3), or for investigating important drivers and variables. In the latter type of analysis, scenarios are used to test whether certain variables or drivers are, or will become, important in the future in relation to a specific question. By creating scenarios in which these variables are varied in a controlled manner and then projecting the impacts of this change into the future, it is possible to identify which variables or drivers are most significant and therefore need to be considered (Box 4).

Box 3: Modelling local and synoptic-scale influences on ozone concentrations in a topographically-complex region of southern Italy

Using data provided by the National Centre for Environmental Prediction and the on-line coupled Eulerian chemical-weather model WRF/Chem., this study was conducted to identify the influences of synoptic scale meteorology, local-scale wind systems and local emissions on ozone concentrations for the Southern Italian region around Cosenza.

Through creating three different scenarios, the authors investigated the contributions that a variety of sources made to the total modelled ozone concentrations. Through this analysis, they were able to demonstrate that generally the influence of regional emissions on the average ozone concentration was small. However, during periods when mountain-sea wind systems were well developed and synoptic-scale winds were weak, the influence of local emissions from the urban area was at its greatest.

(Schürmann *et al.* 2009)

Box 4: Risk of malaria re-emergence in southern France: testing scenarios with a multi-agent simulation model

The Camargue, in southern France, is considered a potential site for malaria re-emergence due to its suitable climate, number of potential vectors and a population that could be host to the disease.

This paper investigated how plausible changes in the biological attributes of vectors, agricultural practices, land use, tourism activities, and climate would influence the risk of re-emergence in the region through the use of scenarios. Scenarios were created through varying the state and combination of the aforementioned variables, and then using these variables to run the spatially explicit and dynamic multi-agent simulation model known as MALCAM, to calculate the probability of reoccurrence.

Through analysing these scenarios, the authors were able to identify the state and combination of variables that were most likely to result in a re-emergence of Malaria in the region, providing important information for both policymakers and researchers.

(Linard *et al.* 2009)

Anticipatory scenarios

Anticipatory scenarios, or decision-support scenarios, develop paths to pre-determined futures that vary according to their desirability. Anticipatory scenarios are therefore often value laden, they are most commonly seen as optimistic scenarios. Because these types of scenarios work backwards from one or more pre-determined futures, it can be said to begin conceptually in the future. By analysing the scenarios created by this process, and the series of steps that are created, it is possible to obtain information regarding the types of actions that need to take place in order for the desired end goal to be achieved, as well as the plausibility of the created storylines. As a result, these type of scenarios are used in the development of strategic options (Box 5).

Box 5: Achieving deep reductions in US transport greenhouse gas emissions: scenario analysis and policy implications

This paper investigates the potential for making deep cuts in US transportation greenhouse gas (GHG) emissions in the long term through using scenarios to explore the plausible ways in which such a significant drop can be achieved.

To achieve this goal, the authors first identified the main Green House Gas Emissions (GHGE) drivers, and created a model which simulates how changes to the transport sector influence these drivers and therefore GHGEs. The modelled scenarios then covered options including a continuation of current trends without change to the transport sector, and options with significant increases in efficiency, lower-carbon fuels, as well as management of travel demand. The model also allowed an evaluation of the effectiveness of the various scenarios.

The authors were then able to evaluate the feasibility and outcomes of various strategies to cut transport GHGEs, as well as better understand the multiple factors involved.

(McCollum & Yang 2009)

Other goal-related categorisations

A type of scenario use that can be considered both exploratory and anticipatory is in impacts analysis. The scenario in this case is the course of action, or the trend that one is interested in. The analysis then involves assessing the impact that this scenario could potentially have on the subject system. The findings of this type of study are often used to inform researchers, policymakers or other stakeholders of the consequences of different types of response to ongoing issues (Box 6).

Box 6: The carbon footprint of water management policy options

A system dynamics model was developed to estimate the energy required to move water from its source to the various distribution laterals of the Las Vegas Valley and to analyse the carbon footprint associated with this process.

Having created and tested the model, the authors then calculated the energy use and CO_2 emissions associated with different water management policy scenarios. Through modelling the impacts of different plausible options the authors aimed to provide a tool for decision makers to assess the possible outcomes of their actions.

(Shrestha *et al.* 2012)

While the overarching categorisation of exploratory or anticipatory scenarios makes very practical distinctions, other terms are also used in the literature to refer to very similar concepts. These terms are used to describe the important characteristics of both exploratory and anticipatory scenarios.

For example, exploratory scenarios can also be referred to as '*descriptive*', '*reference*', '*baseline*' or '*non-intervention*' scenarios depending on interpretation, which all explore plausible futures, while anticipatory scenarios can be referred to as '*normative*', '*prospective*', '*strategy*', '*policy*' or '*intervention scenarios*' as they describe paths to preferable futures. The issue of norms is contentious in scenario development as it could be argued that all scenarios are normative because all scenario developers have their own interpretations, values and interests, but both terms appear in the literature.

The scenario's role in analysis

Another way to capture the diversity of approaches to scenario development and use is by examining the role of the scenario in the analysis as in van Vuuren *et al.* (2012).

Reference scenarios

Reference scenarios are exploratory scenarios which describe the future in the absence of specific interventions to address environmental problems and are commonly referred to as '*business-as-usual*'. They do not imply that things do not change, but rather that they continue on their current trajectories, following existing trends. They are used to provide a reference against which scenarios of change are compared in order to measure, for example, the relative costs and benefits of adopting new strategies or policies (e.g. Box 5), the effect of a change in driving force or the effect of different environmental conditions (Alcamo, 2008).

Scenarios of change

Whereas reference scenarios provide a 'default' view of the future, an anticipatory scenario of change refers to a scenario developed to illustrate a future that is being shaped by a particular course of action or set of variables. Scenarios of change should be developed when the goal is to evaluate policy options for achieving particular environmental targets, to evaluate the future environmental and economic impacts of particular policies or when taking into account the uncertainty of future environmental conditions (Alcamo, 2008). These scenario types include common storylines about the environment, economic or social development such as '*global sustainability*' as identified by van Vuuren *et al.* (2012).

The scenario's form

A final common way in which scenarios can be grouped is by the nature of the information that is communicated by the scenario.

Qualitative scenarios
Qualitative or narrative scenarios describe plausible futures primarily in a non-numerical form, commonly taking the form of single sentences, storylines, or diagrams. Qualitative scenarios are used when the objective is to stimulate policy ideas, when communication and education is an important goal, when many views about the future have to be included or where modelling tools are not available for quantitative analysis (Alcamo 2008). They are particularly useful in the analysis of complex situations with high levels of uncertainty (e.g. Box 7).

Box 7: 2050 scenarios for long-haul tourism in the evolving global climate change regime

This paper uses qualitative scenarios to explore possible responses of the long-haul tourism industry in the face of ongoing efforts to reduce Green House Gas (GHG) emissions. Unconstrained growth in aviation emissions is clearly not compatible with 2050 climate stabilisation goals.

The scenarios were therefore constructed to explore a number of plausible ways in which the aviation industry might respond, ranging from proactive change to become a positive force for both reducing emissions and promoting development through tourism, to changing too little, too late in a reactive manner, resulting in a failure of the industry due to emissions policies.

By developing such contrasting response options, the authors hoped to represent a very complex system in a simple manner that provides an overview of some of the broad options available regarding long haul transport and GHG emissions.

(Vorster *et al.* 2012)

Quantitative scenarios
Quantitative scenarios describe plausible futures primarily in a numerical form, generating data that can be visualised as maps, graphs, or descriptive statistics. These scenarios are often developed from simulation models (examples in Boxes 1-6). Quantitative models are often first developed as qualitative scenarios, for example in the form of conceptual model diagrams showing the relationships between the different elements of a system. These relationships are then subsequently quantified using modelling.

Scenario development is rarely purely qualitative or quantitative as it is often desirable to combine both elements to make best use of both types of information. Sometimes an iterative process is used where qualitative and quantitative analysis are alternated and used in combination with various modelling approaches (see Box 8).

Box 8: A companion modelling approach applied to fishery management

This study aimed to investigate the management of local fishery resources and to produce recommendations to increase their sustainability. After first creating a model of the system, a number of sessions with local fishers, companies and other stakeholders were conducted, supported by this biological model, whereby the stakeholders took part in a role playing game using the model to initiate collective learning and promote discussion, as they could easily see the outcomes of their decisions through the model.

As part of this game, a number of alternative management strategies were discussed, and these were used as the basis for a number of scenarios which were quantified and subsequently analysed more rigorously using agent-based modelling.

(Worrapimphong *et al.* 2010)

4.5. SCENARIO TYPOLOGIES

Scenario typologies seek to classify the large diversity of scenarios and scenario development approaches by identifying typical features of scenario development to create a common understanding and terminology. Typologies vary in focus. Some focus on characterising the elements of a scenario exercise (van Notten *et al.* 2003), some on design and methods for scenario development (Bishop *et al.* 2007, Wilkinson & Eidinow 2008). Some describe the characteristics of the scenarios themselves (van Vuuren *et al.* 2012), whilst others base their classification on the underlying schools of thought (Amer *et al.* 2013). The main classifications are summarised below.

Van Notten *et al.* (2003) identify scenario types under three overarching themes for scenario development: the *why* (project goal), the *how* (process design), and the *what* (scenario content). Further characterisation within each theme is made through 15 scenario characteristics. Table 1 presents the typology with the poles of the themes (e.g. exploration vs decision support as a project goal) and the scenario characteristics.

Table 1: Scenario typology proposed by van Notten and colleagues (2003).

Overarching themes	Scenario characteristics
A. Project goal: exploration vs decision support	Inclusion of norms: descriptive vs normative Vantage point: forecasting vs backcasting Subject: issue-based, area-based, institution-based Time scale: long term vs short term Spatial scale: global/supranational vs national/local
B. Process design: intuitive vs formal	Data: qualitative vs quantitative Method of data collection: participatory vs desk research Resources: extensive vs limited Institutional conditions: open vs constrained
C. Scenario content: complex vs. simple	Temporal nature: chain vs snapshot Variables: heterogeneous vs homogenous Dynamics: peripheral vs trend Level of deviation: alternative vs conventional Level of integration: high vs low

However, Bishop *et al.* (2007) argue that these characteristics relate more to the overall scenario project (the sum total of the objectives, team, resources and methods employed in the scenario development), than the specific scenario technique(s) used (*i.e.* the systematic means that are used to generate a scenario). Bishop *et al.* (2007) classify scenario designs as either qualitative or quantitative and highlight that there are many ways to conduct scenarios that are both qualitative and quantitative. Bishop and colleagues therefore instead focus on reviewing the techniques used to generate scenarios. They identify eight general types of scenario technique, discussed in more detail in Section 4.6, with two to three variations for each type, or over 24 techniques in total (Bishop *et al.* 2007).

Similarly, Wilkinson and Eidinow (2008) acknowledge the utility of van Notten *et al.*'s (2003) typology for cataloguing scenarios in retrospect, but argue that it is less useful as a means of thinking about scenario design. They therefore propose a new typology that is more explicit in identifying the types of and/or approaches to knowledge underpinning a scenario approach. The three types of scenario development approach identified by Wilkinson and Eidinow (2008) are:

- '*Problem-focused*' scenarios, that tend to see the environment as a quantifiable entity where value judgements do not play any role. They look to describe clear chains of causality. Such scenario development is often based on the extrapolation of historical trends into alternative futures. The implicit assumption in problem-focussed scenario development is that more accurate scientific knowledge is the main basis for better decision-making. The IPCC scenarios are an example of problem-focussed scenarios (Appendix 2).
- '*Actor-focused*' scenarios, which are based on the perception of actors and their relationship to the environment. Instead of using purely quantitative evidence as in problem-focussed scenarios, actor-focussed scenarios can be based on qualitative data from a wide variety of sources. These scenarios aim to enable collaboration and shared learning. The Shell Global Scenarios are an example of such scenarios (Appendix 2).
- '*Reflexive interventionist or multi-agent-based*' scenarios which aim to combine the two previous approaches in a form of action-research, where quantitative data and qualitative information are combined and formal modelling and local knowledge are integrated. As in problem-focussed scenarios, this approach is based on clear descriptions of the environment, but also of the relationships of different stakeholders to that environment. Wilkinson and Eidinow (2008) argue that this approach is suitable for decision-making contexts with highly conflicting interests and that it recognises and addresses the role of system uncertainties (Figure 3).

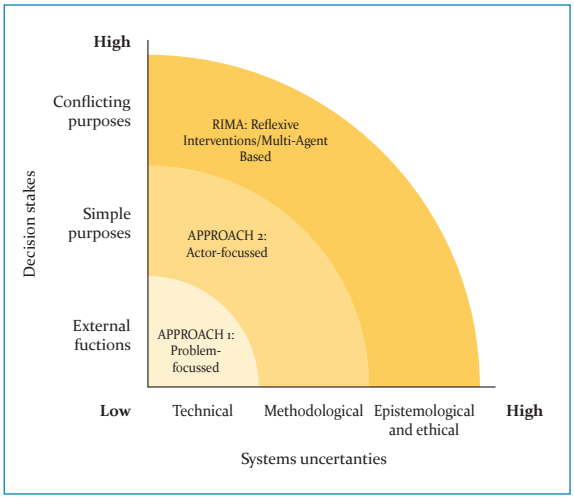


Figure 3: The reflexive interventionist/multi-agent-based scenario approach in a context of increasing decision stakes/uncertainties by Wilkinson and Eidinow (2008).

Whereas the above classifications are based on process and methods, van Vuuren *et al.* (2012) focus on the role of the scenario in the analysis and, through a comparison of global environmental assessment studies, identify six scenario types or 'families':

1. economic-technological optimism/ conventional markets;
2. the reformed market;
3. the global sustainability;
4. the regional completion/regional markets;
5. regional sustainable development; and
6. business-as-usual/intermediate scenarios.

These scenario types are characterised by different key assumptions (Table 2).

Table 2: van Vuuren *et al.* (2012) 'scenario families' and their key assumptions in general terms.

	Economic optimism	Reformed markets	Global SD*	Regional competition	Regional SD*	Business-as-usual
Economic development	Very rapid	Rapid	Ranging from slow to rapid	Slow	Ranging from mid to rapid	Medium (globalisation)
Population growth	Low	Low	Low	High	Medium	Medium
Technology development	Rapid	Rapid	Ranging from mid to rapid	Slow	Ranging from low to rapid	Medium
Main objectives	Economic growth	Various goals	Global sustainability	Security	Local sustainability	Not defined
Environmental protection	Reactive	Both reactive and proactive	Proactive	Reactive	Proactive	Both reactive and proactive
Trade	Globalisation	Globalisation	Globalisation	Trade barriers	Trade barriers	Weak globalisation
Policies and institutions	Policies create open markets	Policies reduce market failures	Strong global governance	Strong national governments	Local steering; local actors	Mixed

* SD = Sustainable Development

Finally, Amer *et al.* (2013), in their thorough review of the scenario literature, discuss several of the proposed typologies. Their review includes a useful comparison of three schools of scenario development: intuitive logics, the French approach of 'La prospective' and Probabilistic Modified Trends (PMT) methodology. A comparison of the three schools is shown in Table 3.

While the above list of typologies is not exhaustive, they illustrate the discussions within the field of scenario development and hopefully help avoid possible confusion on the meaning of the many existing typologies. The practical application of the scenario types and their characteristics are further discussed below.

Table 3: Comparison of the three principle schools of scenario development techniques (Amer *et al.* 2013).

Scenario characteristics	Intuitive logics	La prospective	Probabilistic modified trends (PMT)
Purpose	Multiple, from a one-time activity to make sense of situations and developing strategy, to an ongoing learning activity	Usually a one-time activity associated with developing more effective policy and strategic decisions	A one-time activity to make extrapolative prediction and policy evaluation
Scenario type/ perspective	Descriptive or normative	Generally descriptive	Descriptive
Scope	Can be either broad or narrow, ranging from global, regional, country, industry to a specific issue	Generally a narrow scope but examines a broad range of factors within that scope	Scope is narrowly focused on the probability and impact of specific events
Timeframe	Varies: 3–20 years	Varies: 3–20 years	Varies: 3–20 years
Methodology type	Process-oriented approach, essentially subjective and qualitative	Outcome-oriented approach, which is directed, objective, quantitative and analytical relying on complex computer-based analysis and modelling	Outcome-oriented approach, very directed, objective, quantitative and analytical using computer-based extrapolative simulation models
Nature of scenario team	Usually an internal team from the organisation for developing scenarios	Combination of some members from client organisation led by an expert (external consultant)	External teams, scenario developed by experts (external consultants)
Role of external experts	Experienced scenario practitioner to design and facilitate the process, external experts are used to obtain their views for new ideas	Leading role of external expert using an array of proprietary tools for comprehensive analysis	Leading role of external expert using proprietary tools and expert judgments to identify high impact unprecedented events
Tools	Generic tools like brainstorming, STEEP analysis, and stakeholder analysis	Proprietary and structural tools like Micmac, SMIC and Mactor analysis *etc.*	Proprietary tools like trends impact and cross impact analysis *etc.*
Starting point	A particular management decision, issue or general concern	A specific important phenomenon of concern	Decisions/issues for which detailed and reliable time series data exists
Identifying key driving forces	Intuition, STEEP analysis, research, brainstorming techniques, and expert opinion	Interviews with stakeholders and comprehensive structural analysis using sophisticated computer tools	Curve fitting to past time series data to identify trends and use expert judgment to create database of unprecedented events
Developing scenario set	Defining the scenario logics as organizing themes or principles	Matrices of sets of possible assumptions based on the key variables for future	Monte Carlo simulations to create an envelope of uncertainty around base forecasts
Output of scenario exercise	Qualitative set of equally plausible scenarios in narrative form with strategic options, implications, and early warning signals	Multiple quantitative and qualitative scenarios supported by comprehensive analysis, implications and possible actions	Quantitative baseline case plus upper and lower quartiles of adjusted time series forecasts
Use of probabilities	No, all scenarios are equally probable	Yes, probability of the evolution of variables under assumption sets of actors' behaviour	Yes, conditional probability of occurrence of unprecedented and disruptive events
No. of scenarios	Generally 2–4	Multiple	Usually 3–6, depends on the number of simulations
Evaluation criteria	Coherence, comprehensiveness, internal consistency, novelty, supported by rigorous structural analysis and logics	Coherence, comprehensiveness, internal consistency tested by rigorous analysis, plausible and verifiable in retrospect	Plausible and verifiable in retrospect

4.6. METHODS FOR THE CONSTRUCTION OF SCENARIOS

The review of scenario development methods by Bishop *et al.* (2007) provides a practical overview for non-experts. Their findings are therefore summarised here and supplemented and illustrated with information from other relevant studies identified in the course of this review.

The articles reviewed in the quasi-systematic literature review were classified according to the method that most closely resembled the approach used in the article. For some studies, the method used into multiple categories; where this happened a single paper was assigned multiple method tags. Using this information, the word cloud in Figure 4 was created.

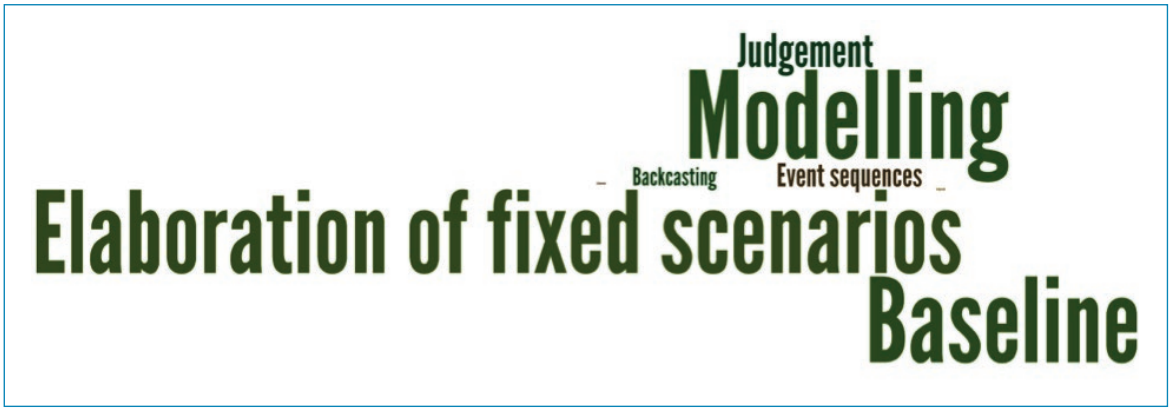


Figure 4: Word cloud of the most frequent methods used in the development of the scenarios from the reviewed articles.

The most common methods used to create scenarios were modelling, baseline creation, and the elaboration of fixed scenarios (Figure 4). This may reflect the scientific bias of papers selected for this review as the more participatory approaches which are commonly referred to in grey literature are less likely to appear. For a broader view of scenario methods used by practitioners, see Henrichs *et al.* (2010).

Judgement

This category of methods creates scenarios primarily based on the judgement of the individual or group describing the future. This judgement is often made unaided, but can use information, analogies, and reasoning to support the assumptions/reasoning of the scenario.

Baseline/expected/trends

This type of approach produces scenarios which are the expected/baseline future state of the system. They can be used, for example, to highlight the differences between a given scenario of change and a baseline scenario of non-intervention.

The most common way of creating baseline scenarios is through the extrapolation of existing trends into the future. This can be done through utilising judgement methods as described previously, or through mathematical methods if empirical data describing the trend exists. Trend extrapolation is a very common scenario technique, and two variants were identified by Bishop *et al.* (2007).

The Manoa technique
This approach is composed of a series of techniques that explore the implications and interconnections amongst trends. The technique requires the individual or group to work with three strong, nearly indisputable trends. These trends are then elaborated, first by discovering the implications of each of the trends separately through the use of a future wheel (a mind-map where each trend forms the centre and successive levels of implications are brainstormed from that). The second elaboration aims to investigate the interactions amongst the three trends using a

qualitative cross-impact matrix (a square matrix with one row and column for each trend. The cells are then filled with the impacts or effects of one trend (the row) on another (the column).
Once these two elaborations have been completed, a rich store of information has been created which can then be used to answer specific questions about the future, or to create scenarios (Schultz 1993).

Systematic Scenarios technique
This is a common variation on the Manoa technique, whereby, rather than using a cross-impact matrix to identify the interactions, the relationships amongst the different trends are recreated using a causal model, which represents the dynamic interactions amongst the variables (Burchsted & Crews 2003).

Elaboration of existing scenarios

This method of developing scenarios takes pre-existing scenarios and elaborates on them in order to create new scenarios which articulate the implications of given alternative futures on topics that the original scenario might not have touched on. Within this broad approach a number of variants were identified.

Incasting
In this method, participants are divided into a number of small groups and are given a small paragraph that describes an extreme version of an alternative future. Participants are then asked to describe the impact of this scenario on a number of pre-defined domains such as law, politics, family life *etc.* (Schultz 2003).

SRI Matrix
This technique begins with a fixed number of scenarios, with each scenario being identified as titles to columns in a matrix such as the expected future, the worst case, the best case *etc.* The dimensions of the world relevant to the question being asked are then listed in the rows, such as population, environment *etc.* Participants then fill in the cells with the state of the domain in that scenario. The whole scenario is elaborated in each column, and the differences for a specific domain are elaborated by looking across the rows (Hawken *et al.* 1982).

Extension via modelling
In addition to the methods in the review by Bishop *et al.* (2007), Sheppard (2012) proposes a method where the outputs from an existing scenario, for example one of the IPCC scenarios, was taken and used to drive a further model. This creates scenarios that elaborate the existing scenarios by detailing how they would impact on a particular system (Sheppard 2012). Using this approach, pre-existing scenarios can be made appropriate for a specific study without changing the purpose of the scenarios, for example by downscaling them so that they can be used at the scale appropriate for a local study.

Event sequences

This type of approach is based on the fact that one can think of the past as a series of connected events, where, at a given point in time, different events could potentially occur. The subsequent events then depend on the specific event that took place earlier. This concept can be applied to the future in the same way, the difference being that one does not know for certain which event will happen. Below are a number of approaches based on the concept of event sequences.

Probability trees
To overcome the fact that we do not know what will happen, we can instead assign each event a certain probability of occurring. Series of connected events and their probabilities form a probability tree. Two major variations of probability trees are described by (Bishop *et al.* 2007), one which uses the branches generated to create scenario themes, and the other which builds the sequences after the events have developed (Buckley & Dudley 1999; Covaliu & Oliver 1995; Lisewski 2002). The specific future that one ends up in depends on the path taken, and if each event is associated with a probability of occurring then it is possible to calculate the probability of arriving at any given final state.

Sociovision
This technique starts with a standard probability tree and then undertakes a close examination of the tree, looking for branches that have a common character. For example, it may be that

many of them are less likely, or more preferred, or may be driven by a particular stakeholder or event. By gathering these branches together, a coherent scenario can be developed complete with the events that make up the scenario. The probability tree therefore acts as an input revealing macro themes that might not have been obvious at the start of the process (De Vries 2001).

Divergence mapping
This technique involves brainstorming a set of events that could feasibly change the future. These events are then arrayed in a fan-like structure in four arcs, each of which represents a longer time horizon, and where each arc is made up of events that happen in a similar timeframe. Events from earlier time horizons are then linked with later ones in a plausible sequence that forms the storyline of a scenario (Harman 1976).

Fuzzy Cognitive Maps (FCMs)
Another method for developing scenarios, which was not included in the review by Bishop *et al.* (2007) and can be considered under 'event sequences', is that of FCMs. FCMs are an enhancement of causal cognitive maps, which visually represent systems as interconnected, directed graphs consisting of nodes and arrows; nodes representing various influencing concepts (which can be a state, variable, objective *etc.*) and arrows the causal relationships between them. Each concept is influenced by the other interconnected concepts based on the values of the corresponding causal weights. The process can capture diverse expert mental models and facilitates system thinking.

FCMs allow the modelling of complex chains of causal relationships through weighted causal links, and analyses the interrelations between the phenomena that are graphically represented in causal cognitive maps. FCMs are often used to support decision-making processes by investigating causal links among relevant concepts. The use of FCMs in scenario development is new but promising as it is a powerful modelling technique that can help overcome the lack of integration between quantitative models and qualitative storylines. FCM uses fuzzy logic, which allows the integration of qualitative analysis (Amer *et al.* 2013).

Backcasting

Backcasting was created to solve the problem that those scenarios that are developed by looking at the world today and then moving forward into the future often are "too safe" in their assumptions, and lack the boldness that is necessary when trying to explore the future. Backcasting starts by envisioning a future state at a particular time horizon and then working backwards from this future state to the present day state in order to identify the sequence of steps necessary to prompt the transition from one state to the other. A number of variants of backcasting exist.

Horizon mission methodology
This variant differs from the above description by promoting creative thinking in terms of the future state that is the starting point of this method. By aiming for a state that at first thought might appear to be impossibly optimistic, and then working out the steps necessary to achieve this goal, a scenario is created that explores avenues that might otherwise seem insignificant in the short term, but might be identified as being crucial at later stages of development (Hojer & Mattsson 1999).

Impact of future technologies
Using classic backcasting methods, this variant only really differs significantly in terms of what the information is used for. In this approach, scenario developers identify likely major technological breakthroughs that would allow them to reach a desired end-state. Then, when the breakthrough finally takes place they will be in position to take maximum advantage of it (Strong 2006).

Future mapping
This technique is a backcasting variant that creates scenarios by pre-defining the end states as well as the events leading up to these end states. Participant teams then select and arrange the events that lead to each end-state; this technique offers participants a deeper understanding of how events can interact to create different futures and how different end-states can occur from the same set of events (Mason 2003).

Dimensions of uncertainty

As discussed previously, one of the major challenges facing the development of scenarios is uncertainty; uncertainty in how humans respond to changes, uncertainty in how systems will interact with each other, and uncertainty in how unpredicted events might influence other events and outcomes. This approach identifies specific sources of uncertainty and then uses them as the basis for creating scenarios. Dimensions to uncertainty are composed of drivers (uncertainties) that are considered highly important for future change but with high levels of uncertainty associated to them, such as, for example: regional integration, governance, decentralisation and consumption patterns. Relatively certain drivers are, for example, population and climate change. There are several variants to the approach.

There are also different perspectives of how to approach uncertainty – representing different practices and underlying philosophies. Some approaches are positivist and work on the basis that predicting 'most likely' futures is possible, while others constructivist, focusing on engagement with, rather than reduction of, future uncertainty, this school of thought is mainly interested in subjective plausibility. Wilkinson and Eidinow (2008) provide an overview of these scenario approaches and also suggest a third approach combined approach.

Axes Method
The most commonly used method for creating scenarios, the "axes method" is based on two dimensions of uncertainty (e.g. Schoemaker & van der Heijden, 1993), for each of which two opposing states or polarities are defined, *e.g.* "Countries in East Africa will integrate politically and economically or remain fragmented" or, "Governance in East Africa will be reactive or proactive". Combining the two uncertainties in a 2x2 matrix then creates four combinations, each containing a plausible future scenario that is then elaborated into a complete story, incorporating other relevant drivers identified during the process (Schwartz 1991). The axes method is used in most global scenario studies such as the IPCC SRES, Millennium Ecosystem Assessment, Global Environment Outlook and others.

General Morphological Analysis (GMA) and Field Anomaly Relaxation (FAR)
The major difference with the axes method, is that in GMA/FAR any number of uncertainties can be used, rather than just two, and these uncertainties can be in any number of states rather than just the two extremes used in the axes method, thus generating a much larger number of plausible scenarios (Coyle *et al.* 1994; Coyle 2003; Duczynski 2000; Eriksson & Ritchey 2002; Rhyne, 1974, 1981, 1995). FAR, a form of GMA developed for policy analysis and future studies, basically maps the plausible interactions between the drivers of change (uncertainties) and their states. Combining all the uncertainties and their states can yield a very large number of plausible scenarios. Different techniques and software (e.g. MORPHOL) exist to reduce the number of combinations and select the most diverse and plausible scenarios. This can include user/expert input, for example by eliminating combinations that are considered impossible (Godet & Roubelat 1996).

Cross-impact analysis (CIA)

The probability of an event or driver state occurring in the future is often dependent on other driver states or events, which can strongly influence the relative probability of occurrence of a particular scenario composed of these events. CIA helps to identify the most plausible scenarios, but also to identify combinations of drivers and states that one would not have included initially.

CIA techniques create scenarios through a matrix approach that evaluates the change in the probability of a particular event occurring following the occurrence of another event. "By placing the various events in a square matrix, with each condition or event occupying one row and one column, it is possible to display not only the initial probability assigned to a condition or event, but also the conditional probabilities of the condition or event given the occurrence of any other condition or event. Using these estimates, a random number between 0 and 1

is chosen. Events with a probability above that number are said to occur, those below are not. The probabilities of all events are then adjusted (up or down) based on the contingent probabilities in the matrix. Running the matrix many times in this manner produces a distribution of probabilities for each that can be used to estimate the probability of that event given the possible occurrence of the other events" (Bishop *et al.* 2007).

This approach produces both scenarios and an estimate of the probability of that scenario occurring, given the events that make up its composition. A well-known CIA analysis was conducted as part of the INTERAX (Interactive Cross Impact Simulation) programme. At its core, the programme has a database containing information on a broad range of long-range strategic issues and future trends and events, which was developed through a large Delphi study of experts (Enzer 1981).

Two variations of CIA are described below:

Cross-Impact Matrices and Systems (SMIC-PROB-EXPERT)
This tool is part of the 'La prospective' school of scenario development. It creates the cross-impact matrix of conditional probabilities based on expert consultation, where experts are requested to assign a probability to an event occurring on a scale of 1-5 and to evaluate the conditional probability of an event occurring if the others occur or not. Using the mean probability assigned to each plausible future by the whole set of expert groups, the SMIC-PROB-EXPERT software programme then creates a hierarchical rank of future scenarios, based on their probability. This can be used to create clusters of scenarios to show which are considered most likely, and which experts' probabilities are most similar (Godet *et al.* 2003). For the selected scenarios (with high or even low probability) the narratives or pathways from present to the different futures then still need to be written.

Interactive Future Simulation (IFS)
This method aims to calculate the quantitative conditions associated with different scenarios. IFS begins with a set of 'descriptors' (trends, events, factors, drivers) that are important for understanding the future, rather than with events or binary conditions as in the other techniques. Alternatives states (values) for each descriptor are defined and assigned an *a priori* probability of occurrence at the target date of the future, based on trends and reasoned expectations by experts. These *a priori* probabilities are used as a starting point for calculating *a posteriori* probabilities resulting from new information based on review by other experts.

The IFS approach generates scenarios as follows: "The a priori probabilities placed on alternative states for each descriptor will sum to 1.0. Each *a priori* probability reflects a degree of uncertainty about a future outcome. New information will adjust the *a priori* probabilities for each descriptor so that the result will be that one alternative future will have an *a posteriori* probability of 1.0 (it will occur) and the alternatives states for each descriptor will have *a posteriori* probabilities of 0 (will not occur). Occurring and non-occurring descriptor sets are organised into scenarios. Alternative scenarios happen when at least one occurring descriptor state differs from another set (scenario)" (Millet 2008).

The IFS computational approach makes use of a cross-impact matrix to adjust the *a priori* probabilities for each descriptor state. The descriptors and their alternative states are on each axis and the cells are given an index value (-3 to +3) reflecting how the occurrence of one descriptor state would influence the *a priori* probabilities of all the others (Millet 2008).

Modelling

This method is most commonly used for baseline forecasting – producing an expected future. Fundamentally based on equations that relate the effects of one variable onto another, modelling methodologies most commonly output figures or graphs that show the change in the modelled variables from the present to the time horizon. A number of variants exist and are discussed below.

Trend Impact Analysis (TIA)
This quantitative approach is a combination of statistical extrapolations with probabilities and is based on the concept that a scenario can be created through adjusting the trajectory of a baseline trend, which has been created according to the probability of occurrence of a plausible future event and its impact, as identified through expert judgement using historical data. In the course of following the method three different points of impact are identified and estimated: the time to the first noticeable impact, the time to the maximum impact and time to the steady state impact. The size of the maximum and steady state impact are also identified. Using this information a new trend line can be drawn and compared to the original baseline to create a scenario (Gordon 2003a, 2003b). An unprecedented event with higher impact is likely to swing the trend relatively far in any direction from its un-impacted course (Amer *et al.* 2013).

The TIA methodology shares similarities with CIA methodologies. However the latter incorporates additional complexity by considering *a priori* probability of occurrence of multiple events.

Dynamic scenarios
This approach uses a combination of scenario development and systems analysis. The first step involves generating a number of events of a similar type from a brainstormed universe of all plausible future events. Events of the same type are then brought together into themes and the system created is then mapped using causal models. The variables that appeared in many different models are then brought together in a meta-model that aims to map the whole domain. The individual themes themselves are then elaborated using different values for the uncertainties in the individual models (Ward & Schriefer 2003).

Advantages and disadvantages of different methods

Using a combination of the list of advantages and disadvantages produced by Bishop *et al.* (2007) in their overview of scenario methods and lessons gathered from analysing the literature, the following section aims to provide an overview of some of the advantages and disadvantages of each of the methods for developing scenarios (Table 4).

Table 4: Advantages and disadvantages of identified methods (adapted from Bishop *et al.* 2007).

Judgement	
Advantages	**Disadvantages**
● Conceptually easy to do. ● An intuitive way of thinking about the future. ● Stakeholders from a variety of backgrounds can be brought in to contribute to the scenario process increasing its validity.	● Difficult to do well. ● Opaque methodology. ● Relies on the credibility of the individual/group. ● Can be hard to generate unexpected event or "surprise". ● Replication of results is difficult to achieve. ● Relies on having people "think outside the box".
Baseline	
Advantages	**Disadvantages**
● Easiest for audience to accept because generally expected already. ● Manoa – highly elaborated, creative, lots of detail. ● Systematic scenarios – show dynamic relationships among scenario elements. ● Trend impacts – links events with trends. ● Provide a means of highlighting the impact of different scenarios.	● Provides no alternative scenarios. ● Manoa and Systematic scenarios techniques require training and experience to do well. ● Trend impacts – requires judgement to estimate impacts, best done with groups of experts. ● Validity relies on a good understanding of the sector under examination. ● Difficult to include the effects of "surprising" events.
Elaboration of existing scenarios	
Advantages	**Disadvantages**
● Easiest method for stakeholder participation. ● Provides in-depth elaboration of alternative scenarios. ● Elaboration through modelling – can gain credibility through using widely accepted scenarios. ● Provides a quantitative way to elaborate existing scenarios.	● Generic scenarios might not be relevant to the stakeholders resulting in less of a buy-in. ● SRI-Matrix – many have an intuitive sense of the best and worst case scenarios already, therefore filling in the cells of the matrix with many rows might become tedious. ● Incasting – wider acceptance of the scenario relies on the credibility of the group. ● Elaboration through modelling – relies on the input scenario having high quality data. ● Often requires high-resolution data that doesn't exist, requiring reliance on downscaling.

Event Sequences	
Advantages	**Disadvantages**
• If probabilities at each branch point are known, it is possible to calculate the probability of end states. • Allows scenario generation in a very intuitive manner.	• Probability trees, sociovision – events and branch points are usually not sequential in nature and interact in a complex fashion making the creation of these trees difficult. • Divergence mapping – events are not always easy to classify according to time horizon. • Probabilities are often based on expert judgement which can be highly subjective. • Current understanding limits the accuracy of understanding the future. • Unexpected events hard to account for.
Backcasting	
Advantages	**Disadvantages**
• Creative because it decreases the tendency to extrapolate the future based on the past and the present, therefore can provide new insights. • Can result in a sequence of events or breakthroughs. • Can help overcome paralysis generated by the "number of options" through its methodologies. • One of the few methods for incorporating some form of 'surprise'.	• Fantastical nature of the mission or end state might reduce buy-in from the audience. • Impact of future technologies – process for developing signposts and recommendations still opaque. • Future mapping pre-defined end states and events might not be relevant to the audience. • Requires a strong group leader to drive the discussions onwards. • Can end up with scenarios that are not useful if present constraints are not considered.
Dimensions to uncertainty	
Advantages	**Disadvantages**
• Best for considering alternative futures as a function of known uncertainties. • Ease of use for a professional audience, in particular GBN. • Existence of techniques and software to reduce the number of combinations and select the most diverse and plausible scenarios. • Allows for calculating the probabilities of different scenarios if the probabilities of the alternatives are known. • Explicitly deals with uncertainty.	• Less creative because may not consider some novel developments that are not currently considered uncertain. • It can be difficult to meaningfully characterise the uncertainties of the future with just two dimensions in GBN. • It is almost impossible to make valid estimates of the compatibility of influence of all alternatives against all other alternatives when using more than to dimensions. • Morphological analysis and field anomaly relaxation both create very large numbers of possible combinations of variables requiring time for analysis. • Complexity and time/resources required (except for GBN).

Cross-impact analysis	
Advantages	**Disadvantages**
• Calculates the final probabilities of alternatives or end-states based on rigorous mathematical procedures. • SMIC-PROB-EXPERT – adjusts the matrix of conditional probabilities for consistency with the laws of probability. • IFS – allows for the quantitative analysis of alternative future values of important drivers.	• Almost impossible to estimate validly the conditional probabilities or impacts of all alternatives against the others, or else the probability given is extremely subjective.
Systems modelling	
Advantages	**Disadvantages**
• Creates the best quantitative representation of continuous variables that describes the future state. • Strong ability to replicate results.	• Difficult to validate the models without complete historical data. • Calibration of the model requires good historical data, if this data is poor then the model outputs will be of poor predictive power. • Coefficients often reliant on historically set coefficients, if these relationships breakdown in the future model validity decreases rapidly. • High-resolution data sets often required, where not available downscaling methods have to be employed.

4.7. DOWNSCALING AND UPSCALING

Although not a method employed to create scenarios, downscaling is a method extensively used in modelling and therefore in scenario development.

Quantitative scenarios can be downscaled either through a *statistical* method (deriving a statistical relationship between the large-scale variables and a finer-scale variable to transform the large-scale outcomes) or by using *dynamic scaling* methods (using the large-scale output to drive a finer scale specific model).

Qualitative scenarios can be downscaled by assuming that trends are similar across scales. Global-level qualitative scenarios can also be made more applicable to finer scales through the embedding of regionally specific information into the global scenario, increasing its applicability at the chosen scale.

Different methods for downscaling the same scenarios produce different results, which can lead to problems of consistency amongst findings by studies using different methods. Several studies have reviewed the various existing downscaling methods (Diaz-Nieto & Wilby 2005; Holman *et al.* 2009; Luo, *et al.* 2013; Zhang 2007). One of the challenges identified was that no single downscaling method is appropriate for every situation, with different papers reporting different methods as being most appropriate.

In general, upscaling scenarios is considered to be difficult but possible (Kok *et al.* 2007; Ingram *et al.* 2012). An argument for upscaling scenarios is that it adds and enriches larger scale scenarios with local-level information, incorporating the creativity and diversity of local scenarios (Ingram *et al.* 2008). However, Alcamo *et al.* (2008) argue that a lack of a common framework (e.g. drivers, definitions, etc.) limits the utility of upscaling scenarios.

4.8. SCENARIOS ACROSS GEOGRAPHICAL SCALES

Many of the interactions and feedbacks in socio-ecological systems play out over several temporal or geographical scales – so called 'cross-scale' or 'multi-scale' processes. While scenario development exercises commonly focus on a specific scale, they can also be used to address multi-scale processes or to link scenarios developed at different scales where the processes at the different scales directly depend on each other. Climate change globally, for example, will impact biophysical processes similarly across scales, but regional socioeconomic development trajectories can also influence global climate trajectories. It is therefore important to understand which factors are external (the 'boundary conditions') to a regional or local system and to which decision makers have to adapt, and which drivers are internal and can be influenced. Zurek and Henrich (2007) argue that scenarios can be linked across geographical scales in two ways: via the scenario *elements* (the scenarios themselves) or via the scenario development process.

Linkage between scenario elements or outcomes across geographical scales

Zurek and Henrich (2007) distinguish five types of linkages among scenarios across different geographical scales via the scenario elements: for example the driving forces, assumptions, scenario logics, boundary conditions, decision-making paradigms or general outcomes. The linkage types differ in the degree of interconnectedness of these elements. They are:

Equivalent across scales/downscaling the scenarios
Here, the general scenario logic, assumptions and outcomes are simply transferred from one scale to another. This tends to work best going from coarser to finer scales (using downscaling). The advantage of this approach is that the scenarios are fully consistent and can be used interchangeably at different scales to identify how development at the global level might play out at a lower geographic scale. However, this approach depends on the main questions the scenario addresses being relevant or interesting at the regional or local scale. As an example of downscaled scenarios, many climate change scenarios used the global emission scenarios of the IPCC to derive regional emission levels.

Consistent across scales/fixing the boundary conditions
When assuming consistency across scales, the main assumptions, scenario logics and the driving forces and their trends are considered consistent across scenarios, with the coarser-scale scenario providing strict boundary conditions to the finer-scale scenario. Thus, while overall the scenarios will play out in similar ways, some of the concrete outcomes at the various scales may differ. This allows the exploration of similar trends across regions and comparison of their outcomes. Different outcomes can be investigated to help identify differences in conditions (economic, environmental, social *etc.*) among regions. However, there is also a risk of the loss of relevance to decision makers at the finer scale.

Coherent across scales/transferring the scenario logic
Coherent scenarios follow the same scenario logic, based on similar assumptions about the future, but the driving forces, their trends and the outcomes can vary substantially. For example, assuming continued globalisation over the next 20 years, national and local decision makers can reflect on what this means at their geographic scale. Thus, while the outcomes of the scenarios might be quite different, the underlying ideas about the future are the same. This helps to identify underlying assumptions and differences in opinion in decision-making processes. However, it might be difficult to find scenario archetypes that apply to all scales.

Comparable across scales/addressing the same focal issue
Comparable scenarios are largely independent at different scales, but connected by the issues they address or a comparable analytical framework they use. The scenarios can be very different at the different geographical scales and the links between them very loose. Such scenarios give a lot of freedom to explore specific questions that are most relevant for a particular area and geographical scale, whilst still maintaining a link to existing scenario exercises.

Complementary across scales/'borrowing' from similar scenarios
Complementary scenarios may have different logic and assumptions, but selected information from scenarios at one scale feed into scenarios at another. Such scenarios can be developed completely independently, but help illustrate how issues can be perceived differently at different scales or differ in their relevance (see Zurek and Henrich 2007 for more detail).

Coupling the scenario development process at different geographical scales

The scenario development process itself can also be coupled across regions and geographical scales. Zurek and Henrich (2007) distinguish five approaches:

Joint scenario development process
Scenarios at different geographical scales can be developed within a single exercise and by the same group of scenario developers. While this can lead to a high level of consistency between scenario elements, it can omit regionally specific details.

Parallel scenario development process
Different groups of scenario developers can build scenarios at different scales but in 'parallel' processes. They may address the same focal question or use a common conceptual framework, apply the same scenario development and quantification method, or just be in the same physical location. While this method allows for a more specific focus on relevant issues at each scale, while maintaining some consistency in the approach, it can be difficult to maintain consistency across the scenarios.

Iterative scenario development process
Scenarios can be developed at one scale and produced as "drafts" which then become the starting point for scenario development at another scale. The first set of drafts are then revised based on input from the other scale, ensuring consistency/coherence among scenarios at different geographical scales. This method emphasises learning across scales. However, its iterative nature can make it a time consuming process that can be stalled by disagreement over cross-scale processes.

Consecutive scenario development process
The consecutive scenario development process is similar to the iterative process except that the original scenario remains unaltered (such as for example most of the IPCC scenario derivatives). Thus, while derived scenarios benefit from a clear starting point and can be built to be highly consistent, there is less opportunity to learn about cross-scale processes or to compare impacts across scales.

Independent scenario development process
Most scenario development processes at different scales are completely independent of each other. The scenarios may still provide input and information to each other, but do so informally. The benefit is that the scenarios can be tailored to the needs and questions of the decision makers at the scale at which they are developed. Such scenarios can sometimes still be mapped to each other later to analyse differences and similarities. However, scale issues are not explicitly taken into account in the process and cross-scale interactions are likely to be overlooked.

A particular scenario process does not lead to specific degrees of linkage among the scenario elements. Some correlation exists, however, such as when a single group of people develop scenarios for different scales in one scenario development exercise: the resulting scenarios are most likely to be equivalent or consistent. Even, if the developers would, from the outset, aim to develop scenarios that address issues that are specific to a particular scale, they would still be unlikely to use completely different approaches. A joint process is therefore unlikely to yield scenarios that are just complementary (Zurek & Henrich 2007).

4.9. CHALLENGES IN SCENARIO ANALYSIS

This section aims to provide an overview of some of the issues and challenges faced by scenario development practitioners.

'Surprise'

Even though scenarios are designed to describe plausible futures, the futures described are extremely unlikely to unfold in their entirety due to the confounding influence of unexpected event or 'surprise'. Surprising events, also called 'wild cards', are by their very nature hard to predict but they can significantly alter expected economic, environmental, and developmental pathways (see also van Notten *et al.* 2005).

Surprising events are of significant concern in particular in baseline scenarios, as this type of scenario is designed to describe a plausible future when no specific interventions or policies are implemented to deal with the problem under consideration. Surprising events can radically change a baseline scenario, which then makes a comparison with alternative scenarios difficult to interpret.

Accounting for surprising events in scenario development exercises can be difficult as discussions are often constrained by current day perceptions about how the world works, and the ways in which people normally approach problems. Explicitly accounting for surprising events can be achieved, for example, by encouraging creative discussions, or by methodologies which enable participants to work backwards from an ambitious end goal, 'predicting' the surprising events that would need to occur to end the desired end state. Nevertheless incorporating surprising events into scenarios remains a significant challenge and, according to Bishop *et al.* (2007), this is rarely done effectively.

Bishop *et al.* (2007) argue, however, that despite the potential uncertainty introduced due to surprise, this is not a significant problem in scenario development. They argue that baseline scenarios are still valid because even though surprising events will almost definitely change the future in some ways, in the majority of cases it will not change it in every single way. Therefore scenarios still remain useful as a general examination of plausible futures.

Sensitivity, initialising variables, and modelling

With models being relied on extensively to provide a quantitative dimension to scenarios, one of the challenges described by Hulme and Viner (1998), is that of the sensitivity of models to the exact value of the initialising variables.

While high sensitivity in a model is sometimes characteristic of the system that it is trying to approximate, and indeed can teach valuable lessons regarding the interplay of the various drivers captured in the model (see also Section 4.6.6), it is not always a desirable trait, especially when initial data it is uncertain, or possibly of poor quality. Therefore having a model that is highly sensitive to initial starting conditions could result in poor quality predictions of the plausible futures.

Extrapolation of trends from data sets

When building scenarios, data sets or expert advice are often used to create models (both conceptual frameworks and mathematical models) that describe how the world works. When examining how well these systems predict the future, the model often does a very good job at predicting change for the data on which it was built.

However, when this model is applied to a novel environment, there is a risk that the model loses its validity because it is trying to predict something in an environment for which it was not built. This can, in some situations, result in discrepancies between what is modelled and what is observed in reality. Examples are when using models created with data from one region in a different region with very different baseline conditions (*e.g.* climate, soil), or when creating models using historical data and then projecting the model into the future.

A trade-off therefore exists between avoiding extrapolation to environments that might be too novel, which minimises the risk of the model being invalid and therefore producing unlikely predictions, and under-extrapolation which adds little to what is already known of the target system. Inevitably, models have to be extrapolated to a certain extent in order to be of use in the creation of scenarios.

Internal consistency

Internal consistency refers to how well a scenario represents dynamics as they are currently understood, and is necessary for a storyline's plausibility (National Center for Atmospheric Research 2014), particularly for model-based scenarios. For a scenario to be consistent, the combination of logics used must not have any built-in inconsistency that could undermine the credibility of the scenario (European Commission 2014).

Maintaining this internal consistency within a scenario process is a major challenge, requiring thorough planning and an overview of the entire process while building scenarios.

Authority

Models and quantitative methods that produce quantified answers are often more implicitly trusted than their qualitative brethren because of the mathematical processes involved in their creation and the type of output produced.

This can result in a great deal of trust being placed in such models and quantified analysis, although this is rarely justified. The challenge therefore in using models and more quantified methods is to ensure that assumptions made during the modelling process are clearly identified, and uncertainties regarding variables are made clear for the end users so that the outcomes of such models are not used blindly.

Scenarios and decision-making

The ultimate aim of future scenarios in this context is to impact decision-making processes (Vervoort *et al.* 2015). Calof and Smith (2012) recommend that scenarios produce actionable recommendations for policy makers. However, connecting scenarios to decision makers has been a challenges, along with measuring the impact of scenario development on policy-making. To date, there is very little literature that specifically look at the impacts of scenarios in decision-making. Although some impacts are immediate, most are realised over long timescales which makes measuring impacts of specific interventions difficult. Although there are case studies of success when scenarios are used to inform specific national policies. For example, in Honduras, scenarios were used in the development of an agricultural climate adaptation policy and are being used to adapt the implementation of sub-national level plans (CGIAR CCAFS 2014).

Vervoort *et al.* (2014) highlight three challenges to the development and use of scenarios by decision-makers:

1. Ensuring the appropriate scope for action. Scenarios vary in spatial and temporal scale depending on their use. For national decisions, regional scenarios may need to be downscaled and revised to be relevant to the national context. The timescale may also be changed to reflect the timescale of particular policies, or may be used in conjunction with other scenarios e.g. global climate scenarios.
2. Moving beyond intervention-based decision guidance to a more embedded processes whereby stakeholder are continuously engaged.
3. Developing long-term shared capacity for strategic planning. The scenario process is currently being strongly driven by research organisations and more focus needs to be put on building the capacity of decision makers and their organisations to lead such processes and integrate them into daily decision-making practices.

5. Conclusions and recommendations

This review sought to synthesise the information available in the large amount of peer-reviewed material published on scenarios. It sought to enable those who are considering using scenarios in their work to navigate the terminology, better understand the function of scenarios, how they are used and the different scenario development approaches and methods.

CONCLUSIONS

The quasi-systematic review focussed on scenario-related literature in the environment field, which explains the importance of climate change as a focus area in the results. Additional papers and review studies yielded information on the use of scenarios for environmental change driven by socio-economic development and uncertainties. Appendix 2 provides examples of a number of different (global) scenarios.

There are a large number of terms in the literature relating to the goal, role and form of scenarios that refer to very similar concepts. Typologies depend on the schools of thought and emphasis (design, techniques etc.) of various groups of authors. As a result, there is much semantic and technical overlap. We have tried to untangle the available information as much as possible and provide an overview of the options in terms of methods. The choice of methods is highly dependent on a project's objective and the role it seeks to give to scenario development and analysis (e.g. Box 9).

Independently of the method used, most scenario development processes enable actors to participate in an integrated analysis of the contextual factors of change for decision-making and explore new strategies, for example on climate change adaptation and mitigation, land-use planning and economic development (Box 9). They enable the consideration of uncertainties regarding future developments in particular when exploring ways to simultaneously improve food security, environmental conservation and rural livelihoods. Techniques such as downscaling/upscaling and linking scenarios across geographies can be important when adapting existing scenarios to the different scales of analysis that practitioners work at.

The use of scenarios is an important tool to support objectives on increasing the understanding and consideration of synergies and trade-offs among different natural resource-based development activities - such as investments in agriculture or extractive industries - environmental conservation and socioeconomic goals. In this regard, the ability of scenario development and analysis to bring together decision makers and other stakeholders from different sectors in a more integrated approach to policy development and review is particularly useful.

RECOMMENDATIONS

It is beyond the scope of this review to provide a detailed set of recommendations on how to develop and use scenarios. However, for scenarios to be effective they must be inclusive, credible and legitimate with ownership and capacity of implementation based at the home organisations of decision makers.

This review found a number of recommendations for those who are considering developing and using scenarios. Three important things to consider, which can be overlooked, are:

1. Start by defining the goal of using scenarios which will determine the best method and the appropriate scale
2. Explore using a mixture of qualitative and quantitative techniques
3. Build capacity in decision makers to develop and use scenarios in order to encourage co-ownership and continued engagement with relevant stakeholders

The review also highlighted that literature on the impacts of scenarios on decision-making is limited. We therefore also recommend that organisations using scenarios to inform decision-making measure the impact of such processes to avoid perpetuating bad, ineffective and non-inclusive scenario practice.

Box 9: Assessing the potential impacts of regional socioeconomic scenarios on land-use to support policy development

Under UNEP-WCMC's Commodities and Biodiversity project (wcmc.io/commodities) regional scenario development was undertaken for countries in the Mekong and Andean regions through a collaboration with the CGIAR's programme on Climate Change, Agriculture and Food Security (CCAFS). Within the *Commodities and Biodiversity* project, four qualitative anticipatory scenarios of change in each of three regions were developed in a participatory process, using methods based on backcasting and dimensions of uncertainty. These scenarios, and others for the East African region previously developed by CCAFS, were subsequently quantified through modelling and used to assess the potential implications of socioeconomic scenarios for land use change and consequently biodiversity and ecosystem services in the three regions. Within the *Commodities and Biodiversity* project, scenarios were used to help test plans and policies on agriculture development and climate change in the different countries in the three regions, and sought to improve their robustness in the face of highly uncertain future developments. The scenarios process also helped generate shared engagement and build relationships between actors that do not normally have much opportunity to interact (for more detail see https://ccafs.cgiar.org/scaling-out-scenario-guided-policy-and-investment-planning).

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Appendix 1: Literature search and screening

Quasi-systematic literature review

Construction and subsequent evolution of the search term

In order to capture as many of the relevant publications as possible while keeping the number of papers within an assessable amount, a simple search term was created using three key words: “Scenario”, “Local” and “Global”.

These key words were combined with Boolean logic operators so that for a paper to be captured by the online search engines it had to include “Scenario” and either “Local” or “Global”. Using global or local increased the relevance of the search results by removing literature that used the word "scenario" in a different context to that used in this report.

Given the scope of this review to specifically review the use of scenarios in the environmental sector, it was felt appropriate to further limit the research areas analysed to just literature that is environmental.

The search terms used are shown below, due to differences in the syntax of the two search engines the original search term had to be translated into the equivalent statement for each.

- *Scopus search term:*

TITLE-ABS-KEY("scenario*") AND TITLE-ABS-KEY("global" OR "local") AND (LIMIT-TO(SUBJAREA, "ENVI"))

- *Web of science search term:*

“Scenario*” AND
“global” OR “local”

Search results generated by Web of Science using this search were then further refined by liming to “Environmental Sciences Ecology”, in order to make the search terms equivalent.

Paper selection process

Table A1: Results of the online database searches and application of the selection criteria

Stage	Papers included	Papers excluded
Raw number of papers collected	36,240	
Number of duplicates removed		17,693
Number of titles reviewed	18,547	
Number of papers excluded on title		8,740
Number of abstracts reviewed	9,807	
Number of papers excluded on abstract		7,695
Total number of papers to review in full	2,112	
Total number of papers randomly selected and reviewed in full	**116**	

Data extraction

Each article that was identified for review was read in full. A series of questions regarding the use of scenarios were then answered to provide the material for this review (Table A2).

Table A2: Questions asked of each paper

Questions:	
Which user group does the paper refer to?	At what scale is the study performed? - If appropriate, what region does it focus on?
What broad area does the paper focus on?	What data sets does the paper use in relation to its scenarios?
What question does the paper seek to answer?	Do any (numerical) models used in the paper make use of scenarios?
How are scenarios used to answer this question?	What method was used to create the scenarios?
Does the paper generate new scenarios? - If yes how were the scenarios generated? - If no does the paper make use of existing scenarios? - If yes what existing scenarios are used?	Are any downscaling methods utilised? - If yes which downscaling method was utilised?
Are the scenarios used qualitative, quantitative or qualitative scenarios that have been quantified?	Were any issues raised about the method?

List of 116 papers from the quasi-systematic review process

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Appendix 2: Examples of scenarios

The following section contains a series of global projects that have made use of scenarios.

IPCC

Founded in 1988 by The United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), The Intergovernmental Panel on Climate Change (IPCC) was established in order to review and assesses the most recent scientific, technical and socioeconomic information produced worldwide relevant to the understanding of climate change and its environmental and socioeconomic impacts.

The IPCC Special Report on Emissions Scenarios
First published in 2000, the IPCC **Special Report on Emissions Scenarios (SRES)** used scenarios to contribute towards understanding the role and relative strengths of the many interacting factors that combine to influence greenhouse gas emissions (GHGE), and to assess the associated uncertainties with these drivers as we look into the future (IPCC 2000).

The IPCC SRES were created to illustrate a number of plausible future emissions scenarios, with the deliberate exclusion of any policies addressing climate change. From the resulting scenarios that were produced, it was broadly concluded that future emissions, even in the absence of specific emissions policy, depend very much on the choices people make, how economies are structured, which energy sources are preferred, and how people use available land resources.

Four broad groups of scenarios were created as part of the IPCC SRES (IPCC 2000):

- The **A1** storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into four groups that describe alternative directions of technological change in the energy system. Two of the fossil-intensive groups were merged in the Summary for Policy Makers.
- The **A2** storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally-oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.
- The **B1** storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

- The **B2** storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Following the broad definition of the drivers that each scenario would address, and the rough direction in which the scenario was heading, six modelling groups were then invited to further implement and develop quantitative scenarios based on these narratives.

This process ultimately resulted in a total of 40 quantitative scenarios (IPCC 2000). Within each family, one of these quantified scenarios was defined as the marker scenario with the other scenarios within the family being classified as either harmonised or non-harmonised, in relation to those of the marker scenario, depending on their assumptions for specific key drivers: population, gross domestic product and energy consumption (IPCC 2000).

In the SRES process, each modelling group provided a complete set of results for each quantitative scenario produced. This theoretically allowed for the exploration of uncertainties arising from different characteristics of these models (i.e. comparisons across scenarios within a family) and uncertainties from looking into the unknown future (i.e. comparisons across scenario families). However, this necessitated an important sacrifice in terms of spatial comparison. Since the various models employed to create the scenarios made use of different regional classifications, all had to aggregate their results to a standardised set of four regions: OECD90, Africa and Latin America, Asia, and countries undergoing economic reform.

The storylines and their quantified counterparts were designed to represent the playing out of certain social, economic, technological, and environmental paradigms, and were deliberately designed to be neutral in that no single scenario is 'better' or 'worse' than any other (IPCC 2000).

Scenario process for the 5th Assessment Report

The SRES scenarios followed a very linear process that was very time consuming. In 2006, the IPCC decided on a new scenario development process that would be shorter and would catalyse the development of new scenarios emerging from the research community.

Rather than starting with detailed socio-economic scenarios that give rise to alternative GHGE, the new four scenarios take alternative futures in global greenhouse gas and aerosol concentrations as their starting point, referred to as Representative Concentration Pathways (RCPs) (Table A3). The RCPs are not associated with unique socio-economic assumptions or emissions scenarios but can result from different combinations of economic, technological, demographic, policy and institutional future. The RCPs can then be used in parallel with Earth System Models, to explore future changes in physical and biogeochemical responses, and Integrated Assessment Models (IAMs), to explore alternative socio-economic conditions. The old and current approaches are outlined in Figure A1.

Table A3: RCP descriptions and citations (IPCC 2014).

	Description	IA Model	Publication – IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m² in 2100.	MESSAGE	Riahl *et al.* (2007) Rao & Riahi (2006)
RCP6	Stablilisation without overshoot pathway to 6 W/m² at stabilisation after 2100	AIM	Fujino *et al.* (2006) Hijioka *et al.* (2008)
RCP4.5	Stablisation without overshoot pathway to 4.5 W/m² at stabilisation after 2100	GCAM (MiniCAM)	Smith and Wigley (2006) Clarke *et al.* (2007) Wise *et al.* (2009)
RCP2.6	Peak in radiative forcing at – 3 W/m² before 2100 and decline	IMAGE	Van Vuuren *et al.* (2006; 2007)

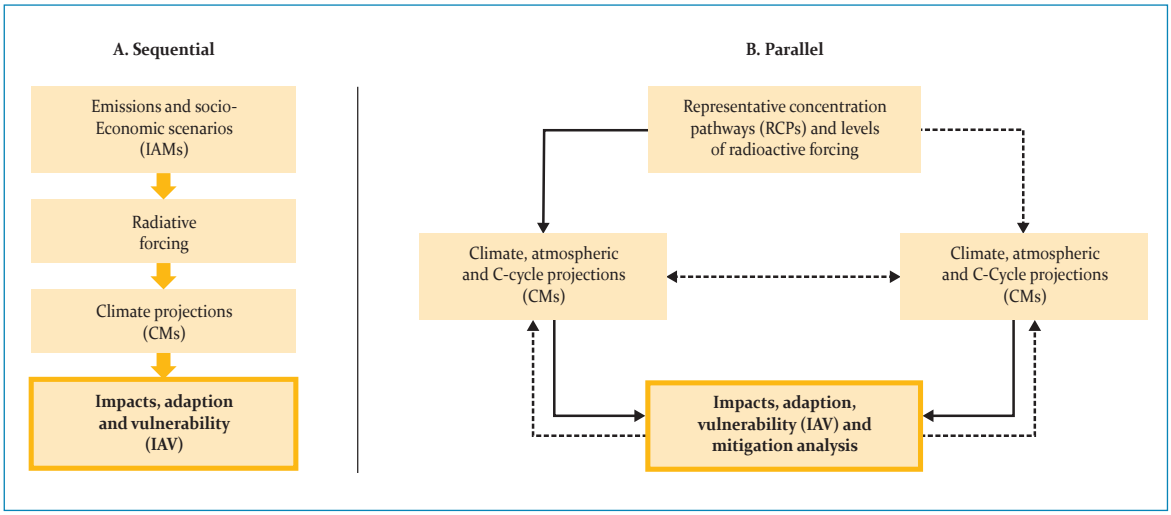

Figure A1: IPCC approaches to the development of global scenarios: (a) original sequential approach, (b) new parallel approach (IPCC 2014)

Scenario development proceeds in three main steps:

- A Preparatory Phase for development of initial data on the major drivers of change in the physical atmosphere, including historical data and future scenarios of greenhouse gas emissions and land use change, to be used in subsequent climate and socio-economic modelling and research (2006-2010).
- A 'Parallel' Phase in which climate and socioeconomic scenarios are developed at the same time rather than sequentially and new impacts, adaptation and vulnerability (IAV) research establishes priorities for the evaluation and application of the scenarios (2009-2012).
- An Integration Phase in which projections and research are brought together to form consistent sets of socioeconomic, climate, and environmental scenarios and to apply them in IAV research (2012 and continuing beyond).

The IAM and IAV research communities have formed an International Committee on New Integrated Climate change assessment Scenarios (ICONICS) to coordinate activities contributing to the Parallel Phase. One goal of ICONICS is to develop **'Shared Socioeconomic Pathways' (SSPs)** that include both qualitative narratives and quantitative elements for use in conjunction with the RCPs. The quantitative projections of the SSPs are documented in an online SSP database.

UNEP GEO Scenarios

The Global Environment Outlook (GEO) lead by the United Nations Environment Programme is a consultative, participatory process that builds capacity for conducting integrated environmental assessments for reporting on the state, trends and outlooks of the environment (UNEP 2014a). GEO is also a series of products which have been designed to help inform environmental decision-making and to facilitate the interaction between science and policy.

Using the Integrated Environmental Assessment (IEA) methodology (UNEP, 2014b), UNEP has produced four GEO reports thus far, which have analysed environmental state and trends at the global and regional scales, described plausible outlooks for various time frames and formulated policy options (UNEP 2014a).

The most current GEO, GEO 5 differs significantly from its predecessors (UNEP 2002, 2007) which have explored several scenarios looking at very different futures. The emphasis of the GEO-5 is instead on the choices and strategies that could, from 2012, lead to a sustainable future. This is advanced by looking at two very different storylines based on a review of existing scenario studies:

- a view of the world in 2050 assuming business-as-usual paths and behaviours – "conventional world" scenarios; and
- an alternative that leads to results consistent with our current understanding of sustainability and agreed-upon goals and targets on the road to 2050 – "sustainable world" scenarios.

A key difference between the two is how deeply transformation occurs, supporting the emergence of alternative development trajectories.

The envisioned sustainable world aims simultaneously to achieve universal human well-being and environmental sustainability at global, national, regional and local levels. The vision assumes that, by 2050, all people have access to food, safe drinking water, improved sanitation and modern sources of energy, all within the ecological limits of the planet. Without major course correction, however, continuing on the current trajectory would lead, by 2050, to major environmental damage, a serious loss of ecosystem services, depletion of natural resources and many people left without sustainable access to food, water or energy. As a consequence, most internationally agreed goals and targets would be missed, some by a wide margin, particularly those related to climate change, biodiversity, water and food security (UNEP 2012).

The review of sustainable world scenarios that was conducted as part of the GEO scenario process suggested that measures can be put in place to help achieve these targets and reduce the risk of Earth System changes and negative impacts on future human development. Measures at the mid layer of transformation, such as rule changes, will not be enough to move to a sustainable world pathway. Structural measures and stronger policy action are needed to influence both production and consumption patterns. Such changes should be both short- and long-term, and combine technology, investment and governance measures along with lifestyle modifications grounded in a mind-set shift towards sustainability and equity-based values (UNEP 2012).

Millennium Ecosystem Assessment (MA)

Produced between 2001 and 2005 the MA assessed the status and trends of biodiversity, ecosystem services and human well-being, specifically focusing on the consequences of ecosystem change for human well-being (Millennium Ecosystem Assessment 2005b).

The MA's main aim was identified from an early stage as being: "to explore alternative development paths for world ecosystems and their services over the next 50 years and the consequences of these paths for human well-being".

As part of the assessment process to meet the overarching goal, scenarios were used to explore a number of alternative development pathways and the subsequent impacts of these paths on ecosystems, ecosystem services and human well-being (Millennium Ecosystem Assessment 2005a). Using mostly exploratory scenario approaches based on a modelling approach, the MA used a fusion of both qualitative and quantitative methods to develop four contrasting broad scenarios, these being:

- **Global Orchestration**
  Depicting a worldwide connected society in which global markets are well developed. Supra-national institutions are well placed to deal with global environmental problems, such as climate change and fisheries. However their reactive approach to ecosystem management makes them vulnerable to surprises arising from delayed action or unexpected regional changes.
- **Order from Strength**
  Represents a regionalised and fragmented world concerned with security and protection emphasising primarily regional markets, and paying little attention to the common goods, and with an individualistic attitude toward ecosystem management.
- **Adapting Mosaic**
  This scenario depicts a fragmented world resulting from discredited global institutions. It sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared towards improving knowledge about ecosystem functioning and management, resulting in a better understanding of the importance of resilience, fragility, and local flexibility of ecosystems.
- **TechnoGarden**
  This scenario depicts a globally connected world relying strongly on technology and on highly managed and often-engineered ecosystems to deliver needed goods and services. Overall, eco-efficiency improves, but it is shadowed by the risks inherent in large-scale human made solutions.

The procedure for building these scenarios was divided into three distinct phases. In the first phase, the scenario exercise was organised and the main questions and the focus of the alternative scenarios were identified through extensive discussion with the end users of the scenarios. In the second phase, the storylines were written and the scenarios were quantified using an iterative procedure. During this iterative process, the qualitative scenarios, developed through consultation with stakeholders in the first phase, were quantified by a team of modellers. The outputs of these models were then passed on to the storyline team which built a storyline around the quantitative data; these storylines were then fed back to the stakeholder group who commented on them before handing them back to the modellers to work on. During the third phase, the results the scenario analysis were synthesised and scenarios and their outcomes were reviewed by the stakeholders of the MA, revised and disseminated (Millennium Ecosystem Assessment 2005a).

Five global models covering global change processes or ecosystem provisioning services and two global models describing changes in biodiversity were chosen and modified where appropriate to assist them in working together.

The variables used in these global models were provided from the initial qualitative analysis which through discussions with key stakeholders and experts identified the key drivers.

Although each one of these scenarios is individually extremely unlikely to occur, by comparing the scenarios and the various paths leading to them it is possible to generate useful information. In this case comparison of the various scenarios allows 'trade-offs' between the various scenarios to be identified, and general lessons regarding policy decisions that move in the general direction of one of the identified scenarios. Other uses of these scenarios include identifying areas where high levels of uncertainty exist for future work, and the identification of 'warning signs' that can aid policy and decision makers in being proactive in their decision-making (Millennium Ecosystem Assessment 2005a).

IAASTD Scenarios

The International Assessment of Agricultural Science and Technology for Development (IAASTD) was a three-year collaborative effort, conducted between 2005 to 2008, initiated by the World Bank and combined the efforts of 110 countries and over 900 participants to produce an international assessment of agricultural knowledge, science and technology (IAASTD 2009).

As part of this assessment process scenarios were constructed as a way of assessing the consequences of plausible changes in development paths for hunger, poverty alleviation, human health, and the environment (IAASTD 2009). Through their construction, and subsequent analysis, scenarios helped to provide an insight into the drivers of change, reveal the implications of current trajectories, and illuminate options for action.

The procedure used to build these scenarios were based on the Millennium Assessment and Intergovernmental Panel on Climate Change (IPCC) methodologies (Scoones 2009), and in a similar fashion to these other assessments seeks to integrate qualitative scenarios built through extensive stakeholder participation with quantitative models and realistic projections in order to create challenging, credible and useful scenarios of the future. The scenario development team from an early stage realised that much of the value of scenarios lies in incorporating both qualitative and quantitative understandings of the system to encourage people to evaluate and reassess their beliefs and assumptions about the system.

The scenario development process that took place therefore consisted of two essential activities. First, the key drivers, variables and feedback effects were identified, along with how they could plausibly change in the future. This was achieved through conducting extensive interviews and workshops with scenario end users. Using these identified variables, four contrasting scenarios were created using the same terminology as used in the MA but reworked so that they specifically address the issues that IAASTD is interested in (Table A4). For each scenario the dominant approach for sustainability, the economic approach for sustainability and the social policy foci were identified to help with the next stage of the scenario development process.

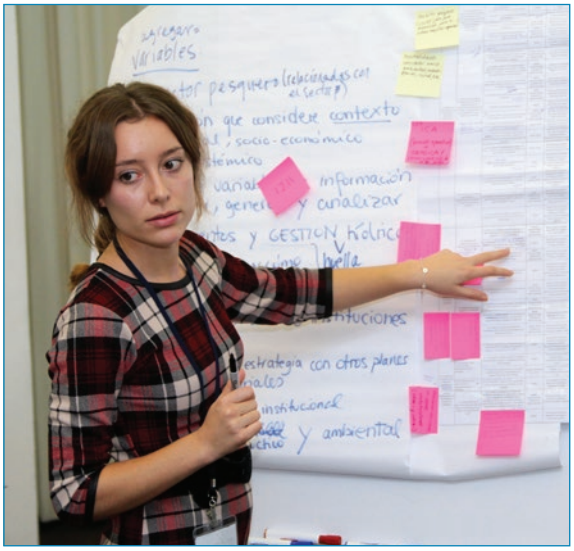

Table A4: IAASTD Scenarios (Rosegrant 2009).

Global Orchestration Focus on macro-scale policy reforms for environmental sustainability	**Dominant Approach for Sustainability** Create demand for environmental protection via economic growth and social improvements; public goods **Economic Approach** Redefinition of the public and private sector roles; improving market performance; trade liberalisation; focus on global public good **Social Policy Foci** Increase global equity; public health; global education
Order from Strength Retreat from global institutions, focus on national regulation and protectionism	**Dominant Approach for Sustainability** Reactive problem-solving by individual nations; sectoral approaches, creation of parks and protected reserves **Economic Approach** Regional trade blocs, mercantilism, self-sufficiency **Social Policy Foci** Security and protection
Adapting Mosaic Retreat from global institutions, focus on strengthened local institutions and local learning	**Dominant Approach for Sustainability** Learning via management and monitoring, shared management responsibility, adjustment of governance structures to resource users, common-property institutions **Economic Approach** Focus on local development; trade rules allow local flexibility/ interpretation; local non-market rights **Social Policy Foci** Local communities linked to global communities; local equity
TechnoGarden Emphasis on development of technologies to substitute for ecosystem services	**Dominant Approach for Sustainability** Green technology, eco-efficiency, tradeable ecological property rights **Economic Approach** Global reduction of tariff boundaries, fairly free movement of goods, capital and people, global markets in ecological property **Social Policy Foci** Improving individual and community technical expertise; policies follow opportunities; competition

Following the construction of these four alternative scenarios, storylines were derived through conducting extensive interviews and workshops (Rosegrant 2009) with scenario end users in order to take account of the broad range of variables and feedback effects that exist, variables considered included: population development, economic development, technology development, demand, human behavior and institutional factors, and to create the inputs for the modeling teams.

Four models were utilised to quantify these scenarios using the model inputs derived from the storylines, these were: IMPACT for world food production, AIM for global change, IMAGE 2 for Global change and WaterGAP for world water resources.

Shell Global Scenarios

Although scenarios have been used academically since the 1950's, it was not until the 1970's that large companies realised the potential benefit of investing in scenario development to help guide their decision-making processes. Starting in the early 1970's the Royal Dutch Shell group was one of the first large companies to invest in scenario development to guide their strategy development (Shell 2014b).

Focusing on investigating surprise and ways to respond to these unexpected events, investment in scenarios helped Shell to weather a number of challenging events, for example, the 1973, Yom Kippur War which triggered an oil embargo against the West. Having actively considered an oil shortage in one of the scenarios it produced in 11972, Shell was in a stronger position, relative to its competitors, to deal with this challenge (Shell 2014a).

Since that time Shell has invested significantly in the use of scenarios and in the development of more practical scenario techniques to support their development. Shell-style scenarios are mainly used to challenge current thinking within the organisation and allow Shell executives to open their minds to previously inconceivable or imperceptible developments (Shell 2014b). Shell's scenario making methods have been strongly influenced by an underlying ethos that scenarios should harness intuition and not fall back on numbers. More recent scenarios however have been associated with quantification to enhance internal consistency, reveal deep story logic and, and illustrate outcomes numerically (Wilkinson & Kupers 2013).

The scenario method employed by Shell is based on structured interviews with decision makers to probe their core concerns, hopes for the future and uncover uncertainties about the company, its business, and its environment (Wilkinson & Kupers 2013). In this way the scenario team is able to create scenarios that are relevant, plausible and address the concerns of policymakers and make a significant impact on the decision-making process. A thorough understanding of the current economic, environmental and political sectors, and investing considerable effort into looking for 'signposts' for the next big "surprises", companies can help themselves prepare for the future.

European Environmental Agency

The European Environmental Agency, in response to the increasing use of scenarios, have generated five scenarios known collectively as the PRELUDE scenarios which focus on exploring the interaction between biodiversity and landscape protection. They highlight a number of factors that could jeopardise their effectiveness and efficiency in the mid- to long-term, such as demographic changes and climate change (European Environment Agency 2014).

For more information please visit: http://www.eea.europa.eu/media/audiovisuals/interactive/prelude-scenarios

OECD Environmental Outlook

The OECD Environmental Outlook to 2050 asks "What will the next four decades bring?" Based on joint modelling by the OECD and the Netherlands Environmental Assessment Agency (PBL), it looks forward to the year 2050 to find out what demographic and economic trends might mean for the environment if the world does not adopt more ambitious green policies. It also looks at what policies could change that picture for the better (OECD 2012).

This Outlook focuses on four areas: climate change, biodiversity, freshwater and health impacts of pollution. These four key environmental challenges were identified by the previous Environmental Outlook to 2030 (OECD 2008) as "Red Light" issues requiring urgent attention.

For more information please visit: http://www.oecd.org/environment/indicators-modelling-outlooks/49846090.pdf

World Water Vision

The World Water Vision exercise, carried out under the guidance of the World Water Commission, was undertaken by a growing recognition that water supplies for human usage are going to come under increasing levels of pressure in the near future. In the creation of these scenarios of how the world can sustainably manage its water resources many thousands stakeholders have been involved in participatory exercises over an 18-month period, with the end product being a shared vision of sustainable water usage in the long term.

For more information please visit: http://www.worldwatercouncil.org/index.php?id=961

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