



# MetaMAP: a graphical tool for designing initiatives to support multiple sustainability goals

Ray Maher<sup>1,2</sup>  · Samuel Mann<sup>3</sup> · Clive A. McAlpine<sup>2</sup>

Received: 23 March 2021 / Accepted: 11 April 2022 / Published online: 2 July 2022  
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## Abstract

This paper presents MetaMAP: a new graphical tool and framework for designing well-integrated sustainability initiatives, and managing synergies and trade-offs regarding the Sustainable Development Goals (SDGs). The SDGs are highly interconnected, but many institutional structures and thinking paradigms lead us to look at them in isolation. This stifles innovation and social transformation. Most tools and frameworks, while valuable, focus on analysis, not design, and are limited to a particular discipline, sector, SDG, or geographic scale. Without holistic frameworks and collaborative tools, many sustainability practitioners may be playing chess without a board. To support a more integrated approach to achieve the SDGs, MetaMAP resembles architectural design tools which help users to synthesise knowledge, reframe complex situations, and identify stakeholders, leverage points, synergies, and trade-offs. MetaMAP applies a new meta-framework to organise concept maps developed collaboratively by interdisciplinary teams following a guided process. This framework integrates components of the natural environment, built environment, and society across multiple spatial and temporal scales. It incorporates concepts from social-ecological systems, planetary boundaries, design thinking, integral theory, ecosystem services, and ecological footprint, among others. MetaMAP was designed with input from over 170 people from diverse disciplines in five workshops, numerous case studies, and critique. This article demonstrates MetaMAP through its application to a case study in which a multidisciplinary team analysed the impacts of an Ecovillage across scales and designed synergetic initiatives. We then critique MetaMAP from four disciplinary perspectives. We envision that MetaMAP will support the design of sustainability initiatives which are more efficient, more broadly supported, and contribute to multiple SDGs simultaneously. By taking a systems view and applying design thinking, MetaMAP helps users to understand interlinkages, maximise synergies, and minimise trade-offs when designing specific SDG initiatives.

**Keywords** Sustainable Development Goals (SDGs) · Synergy · Trade-offs · Decision-support tool · Conceptual frameworks · Cross-scale interactions · Design thinking · Social-ecological systems · Interdisciplinary collaboration · Visual communication

## Introduction and background

The 21st Century will be defined in large part by how we navigate the relationship between human society and the rest of the natural environment, and our trajectory into the future (Meadows et al. 1972; Wackernagel and Rees 1996; Rockström et al. 2009). Currently, our unsustainable society is driving ecological collapse (Barnosky et al. 2011; Ellis 2011) and eroding the future of human civilisation. But our growing knowledge of how society and natural environments are interrelated, new technologies, and new governance frameworks (Dodds et al. 2012; Evans 2012) provide a strong foundation for building a sustainable future.

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Handled by Xin Zhou, Institute for Global Environmental Strategies, Japan.

✉ Ray Maher  
r.maher@uq.edu.au

- <sup>1</sup> Centre for Policy Futures, The University of Queensland, Brisbane, QLD, Australia
- <sup>2</sup> School of Earth and Environmental Science, The University of Queensland, Brisbane, QLD, Australia
- <sup>3</sup> Otago Polytechnic, Dunedin, New Zealand

Notions of ‘sustainability’ seek to reverse trends of decline and establish durable relationships among society, the environment, and our economy, which support healthy natural systems and long-term wellbeing for current and future generations—in short “enough for all forever” (African Elder at Johannesburg WSSD, 2002 as cited in Hopkins 2009).

Since their adoption by United Nations Member States in 2015, the 17 SDGs have provided a common framework for guiding collective action to pursue a wide range of related ambitions (Griggs et al. 2017). In parallel, research on sustainability has developed from relatively isolated issues pursued within academic silos, to a more comprehensive and integrated web of concepts, challenges, and solutions spanning across disciplines (Clark 2007; Miller 2013; Miller et al. 2014). For example, research on social-ecological systems (Ostrom 2009) and resilience (Folke 2006) highlight the connections among SDGs and the need for a more integrated approach (Nilsson et al. 2018; Allen et al. 2019). More integrated initiatives built on a more holistic understanding of issues can help to foresee and manage trade-offs (Griggs et al. 2017), and achieve a better net position on the SDGs (Renaud et al. 2020). Increasing synergy and minimising trade-offs can provide greater total benefit for a single investment, reduce conflict among stakeholders, and build broader support for sustainability initiatives (Nilsson et al. 2018).

Despite their benefits, there are many challenges to developing more integrated initiatives to achieve SDGs. Responsibility for separate SDGs is typically divided among siloed government departments and thematic experts. Entrenched silos within and between sectors, institutions, and communities restrict the sharing of ideas and perspectives (Cornell et al. 2013). Many established thinking paradigms (such as prioritising analysis and relying on single measures) lead us to look at problems in isolation (Strackan 2009), leading to blind spots. Dividing the 17 goals into 169 targets within them, each tracked by numerous metrics, can promote a reductionist approach to implementing them.

The tools and frameworks used to understand issues and make decisions play an important role in overcoming these challenges and developing more integrated sustainability initiatives (Heemskerk et al. 2003; Maher et al. 2018a, b). There are many valuable tools which support investigation and decision-making for sustainability, but most are situated tightly within a particular discipline, sector, SDG, or geographic scale. The SDG Interlinkages Framework (Nilsson et al. 2016) helps to understand typical interactions among selected SDGs at a general level. This supports the argument for achieving SDGs in an integrated fashion but may be of less value for informing specific sustainability initiatives where actual conflicts and synergy depend on unique social, ecological, and political circumstances. The System Dynamics-based iSDG family of models are tools for comparing

and choosing among competing sustainability initiatives (Collste et al. 2017). This is valuable for maximising multiple known sustainability outcomes which align with stakeholder demands. However, the initiatives being assessed must be predetermined using other means. The graphical multi-agent decision-making model (GMADM) (Khalili et al. 2017) also depends on assumed plans or portfolios. While the tool is well formulated, focusing on comparative analysis has limited value for challenging assumptions or generating new ideas on which to build creative and innovative solutions. The SDG tools compendium (Asian Development Bank 2018) introduces 134 tools for helping to address environmental SDGs in Asia. These are sorted into 17 different categories and support critical endeavours including analysis, budgeting, stakeholder engagement, building scenarios and developing measurements. However, none of the 134 tools explicitly support designing sustainability initiatives using established design principles and methods. Tools that prioritise analysis restrict lateral thinking—our ability to perceive and re-conceptualise things in fundamentally new ways (de Bono 1970). This means outcomes tend to optimise and reinforce existing ways of being rather than transformation. In short, these are tools for analysis, not design.

The demands on tools for designing initiatives to address SDGs in an integrated way are tremendous. They must help users to understand interactions among SDGs and address sustainability challenges holistically by synthesising thinking across disciplines and sectors (Hadorn et al. 2008; Scholz and Steiner 2015). These tools must support the practical application of leading sustainability theory (Collste et al. 2017; Lang et al. 2017) and systems thinking (Stafford-Smith et al. 2017), connect intellectual concepts with shared social values (Hall et al. 2017), identify leverage points (Meadows 1997) relative to personal/organisational capacity, and design well-integrated sustainability initiatives with high synergy and minimal perverse outcomes. To be widely used, tools for addressing SDGs must be intuitive, practical, and suitable for diverse users with limited specialist training. Underlying these requirements is a need for tools which support the “creative coordination of resources, capacities, and information into new ways of seeing the system which are useful for designing strategic interventions in the setting” (Hall et al. 2017). Finally, the tools we use to understand and communicate also influence how we think and solve problems (Heemskerk et al. 2003; Allen and Kilvington 2019). Tools to help achieve SDGs should contribute to cultivating a mindset which approaches ‘wicked’ sustainability challenges (Harris et al. 2010) in a holistic and creative way. While existing tools assist strategic decision-making, there are few examples of flexible tools which help diverse, non-expert users to understand sustainability challenges holistically and design well-integrated initiatives which support multiple SDGs. Tools for specialist users,

such as those introduced earlier, are not intended for, nor suited to this role. Holistic thinking requires holistic tools, but without the right tools, many sustainability decision-makers may be playing chess without a board.

Seizing this opportunity, this article presents a new graphical tool/framework/process called MetaMAP for understanding sustainability issues and designing initiatives to address them. ‘Meta’ to represent a higher-level, inclusive point of view, and ‘Map’ to describe its use as a graphic system for organising and navigating concepts and identifying pathways of action. The process of designing MetaMAP collaboratively using Research through Design (RtD) methods was shared via a previous publication (Maher et al. 2018a, b). An early version of MetaMAP was selected by Future Earth and the Stockholm Resilience Centre (Maher 2016) as one of 21 SDG Social Innovation Labs (Westley et al. 2015) and was presented in Stockholm at Resilience 2017 (Maher 2017a) and the International Conference on Sustainability Science (ICSS) (Maher 2017b). Broad interest by delegates from academia, non-government organisations, and governance backgrounds prompted the further development of MetaMAP to enable its use by others.

To that end, this paper first provides a broad overview of MetaMAP and its attributes, then describes six core components and their function. The paper then demonstrates MetaMAP’s application via a case study of an Ecovillage in which a multidisciplinary team examine interlinkages, and propose a high-leverage initiative which maximises synergy and minimises trade-offs to achieve SDGs. MetaMAP is then examined from four different disciplinary perspectives, highlighting its contributions. The article ends with a discussion of some of the limits of the tool and opportunities for further development and application. To increase accessibility to scholars and practitioners from a wide range of disciplines, this article favours common language even when it discusses discipline-specific terms. Graphics are used throughout to demonstrate how MetaMAP facilitates complex thinking with clarity.

## Overview of MetaMAP

### What is MetaMAP?

MetaMAP helps users to apply systems and design thinking to design initiatives which support SDGs with maximum synergy and minimal trade-offs. It acts as a conceptual systems tool to support sense-making, explore different perspectives and interactions among the concepts in the system in a qualitative manner, and facilitate discussions across disciplines and stakeholders. Within this tool, a new organisational framework gives structure to concept maps (conceptual systems models) built collaboratively by

interdisciplinary teams following a guided process. MetaMAP primarily refers to the conceptual framework, analogue visual tools (i.e., paper-based or editable digital images), and guided process which are currently usable for collaborative and independent research, education, and decision-making (Fig. 1). Secondly, in developing and testing the analogue tool, it is also useful to consider it developed into a proposed digital platform with more functionality (see Sect. 4.3).

MetaMAP applies familiar visual metaphors such as a landscape, icons, and colour-coding to guide perception and make complex thinking easier. The organisational framework is described metaphorically as a ‘landscape of ideas’. It allows users to position ideas depending on their scale (personal to global) and according to broad categories of the natural environment, the built environment and society. Users populate this ‘landscape’ with concepts—important components of a sustainability challenge they are seeking to address. For example, these could relate to specific ecosystems, farming practices, energy policy, transport choices, or shared values. The concepts are then linked with arrows to describe how they relate. Users with different experience can work together in adding concepts and links to build and critique their collective understanding of the challenge. The case study below demonstrates how, by following a guided process, MetaMAP can help users to build a shared understanding, identify challenges, opportunities and leverage points, and design initiatives which achieve multiple sustainability goals simultaneously.

### Who can use MetaMAP and in what applications?

MetaMAP aims to support different groups working on sustainability in different but overlapping ways. Some examples of where MetaMAP can help include:

- *decision makers and practitioners* to identify synergies, trade-offs and broader implications of policy and to design initiatives which support multiple SDGs and stakeholders;
- *researchers* to frame projects within a broader context, to identify paths through which they may advance sustainability goals, and to help them collaborate across disciplines;
- *educators and citizens* to explore sustainability concepts, find their place in the system, and identify where they can best contribute to sustainability goals.

Thus far, testing and development of MetaMAP has occurred primarily in an academic environment including teaching, research, and research planning. Other versions of MetaMAP have been used by decision-makers in sustainability organisations and research is underway developing it for industry and government uses. The context of use can



**Fig. 1** Application of MetaMAP in a collaborative workshop with postgraduate architecture students who were previously unfamiliar with systems thinking or the SDGs, but well versed in navigating wicked problems, synergies and trade-offs with design thinking and graphical tools.

vary, including: strategic planning, self-directed inquiry, collaborative workshops, and education (Table 1, Column A). MetaMAP has been applied by collaborators from a wide range of disciplines whose input helped to inform its design (Table 1, Column B), which is described in detail elsewhere (Maher et al. 2018a, b). These independent and collaborative applications have been applied to the development, analysis, and case study of a wide range of projects, mostly by postgraduate research students (Table 1, Column C). These existing applications and further applications proposed by sustainability experts from academia, government, and NGOs demonstrate MetaMAP's flexibility (Table 1, Column D).

### Components of the MetaMAP framework

MetaMAP is composed of six main components (Fig. 2). The Landscape of Ideas (a) is a conceptual plane which organises different concepts related to sustainability in a meaningful way. Concepts (b) represents any part of the sustainability challenge being considered and are represented with colour-coded icons for rapid comprehension. Links (c) use lines and arrows to describe different ways that one concept may influence another. Insight (d) refers to the 'big picture' (higher-order) issues that become apparent when

we consider many concepts interacting over time and from different perspectives. MetaMAP represents these high-level issues as notations and groups. Self (e) represents the individual(s) using the framework and their own place in the system. This helps users to plan achievable actions with far-reaching benefits. Guided processes (f) provide a structured yet agile method of collaborating to understand, strategise and act on complex sustainability challenges. Each of the six components of MetaMAP (a–f) are described next, including its purpose, how it is used and how it is represented visually. This paper then provides an example application of MetaMAP for greater clarity and with additional detail.

a) *Landscape of ideas* – containing realms, categories, scale, cells, and emergent properties

The Landscape of Ideas provides a meaningful structure to a very wide range of issues related to sustainability (Fig. 3). Its grid is formed by two dimensions. The x-axis defines different aspects of human civilisation and the environment. This is divided into 24 different categories, each relating to a different group of issues. The categories are grouped into three realms: the Natural Environment, the Built Environment and Society. This trio, used recently by

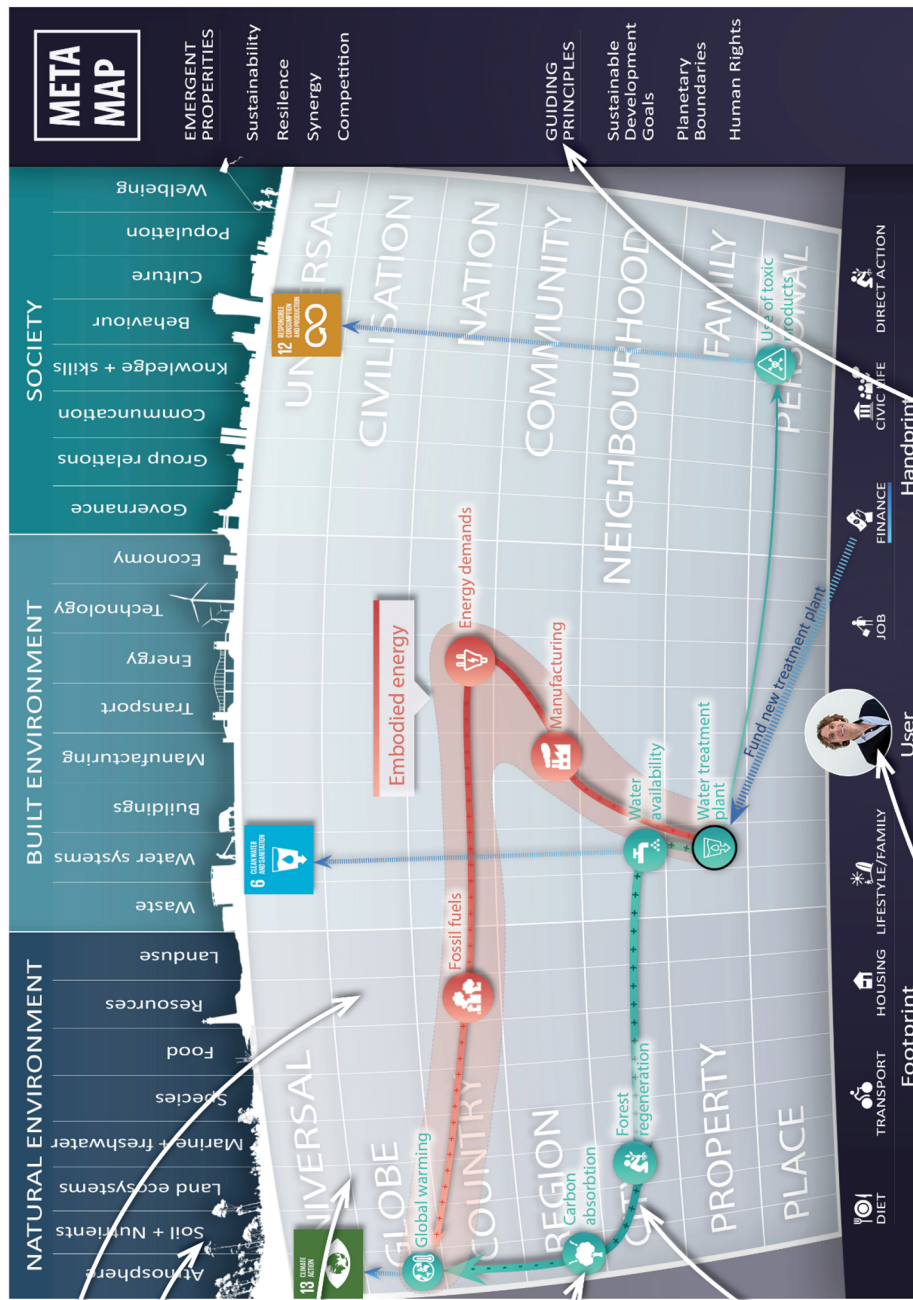
**Table 1** Existing and proposed applications of MetaMAP

A) Type/context of previous use	B) Disciplines of previous users	C) Projects and case studies where MetaMAP has been applied (in Australia unless otherwise noted)	D) Additional applications proposed independently by sustainability experts
Strategic planning of research initiatives	Architecture Ecology	Regional Centre of Expertise application	Resilience planning in South and Southeast Asia
Research activities	Human Geography	Sustainability frameworks	Multiple ecosystem services and urbanisation around Shanghai
Workshops with research fellows and postdocs (1–2 h)	Earth Sciences Environmental Management	Fisheries Ecovillage, Gold Coast	Air pollution in China
Sustainable design interventions by postgraduate research students (7 weeks)	Educational Psychology Participatory GIS Business	Council House 2, Melbourne Global Change Institute, Brisbane	Facilitating Academic-Industry collaboration in sustainable agriculture
Case study projects by postgraduate research students (6 weeks)	Human-Computer Interaction (HCI) Conservation Biology	Habitat social housing, Melbourne	Community development planning in Guyana
Workshops for tertiary education (2 h)	Sustainable Practice	Urban Greening Intervention for King George Square, Brisbane	Cross-scale issues in health systems Organisational strategy for sustainability
		Engineered Timber products West Village residential development, Brisbane	Communicating how SDGs are being addressed in India Management education
		Wickham Terrace Car Park, Brisbane	
		State Library of Queensland, Brisbane	
		Oxley Creek Master Plan, Brisbane	
		Greater Springfield Masterplan, Queensland	
		Apartment building typology Brisbane Common Ground	
		Constance Street Affordable Housing, Brisbane	
		Townsville Hospital	
		Barangaroo Development, Sydney	
		Robina Town Centre	
		South Bank Parklands, Brisbane	
		Chermside Suburban Development, Brisbane	
		Lifecare Cancer Facility, Sydney	

Crosson et al. (2020) is only one possible conception among many, but our Research through Design process engaging 170 users found it to be effective for this purpose (Maher et al. 2018a, b). The realms are intended to help users understand the system rapidly and are only a guide—they are not intended to precisely reflect reality. Some categories may span across realms. For example, food is included within the natural environment even though a lot of agriculture is an industrial process in a landscape shaped by people. The y-axis describes the scale of different issues ranging from small in the foreground (bottom) to large on the horizon (top). The default scale is geographic, shown on the left of Fig. 3. It ranges through place, block, city, region, nation, globe to universal (i.e., applicable to almost all cases and not

tied to a specific scale). However, different disciplines think about scale differently, and a geographic scale is not relevant to all issues. Other scales can be used in parallel such as the social scale shown on the right. Each cell (defined by a particular category at a particular scale) provides a place to locate concepts. Real life is complex and ambiguous so users must take a ‘loose fit’ approach when locating concepts on the Landscape. This framework is designed to be as inclusive as possible to bring together currently isolated people and ideas. It can help us to think and collaborate in many ways which are described later.

It is important to note that while most efforts to advance SDGs are focused at a national or global scale, achieving them requires important contributions at smaller scales. For



**Components of MetaMAP**

**a) Landscape of ideas** - organising framework

X-Axis: Categories  
Different aspects of our social-ecological system grouped as Natural environment, Built environment, and Society.

Y-Axis: Scale  
Concepts are located according to their scale - smallest in the foreground (bottom), and largest in the background (top). The scale is indicative, not definitive. This may represent spacial scale (left) or scales of social organisation (right).

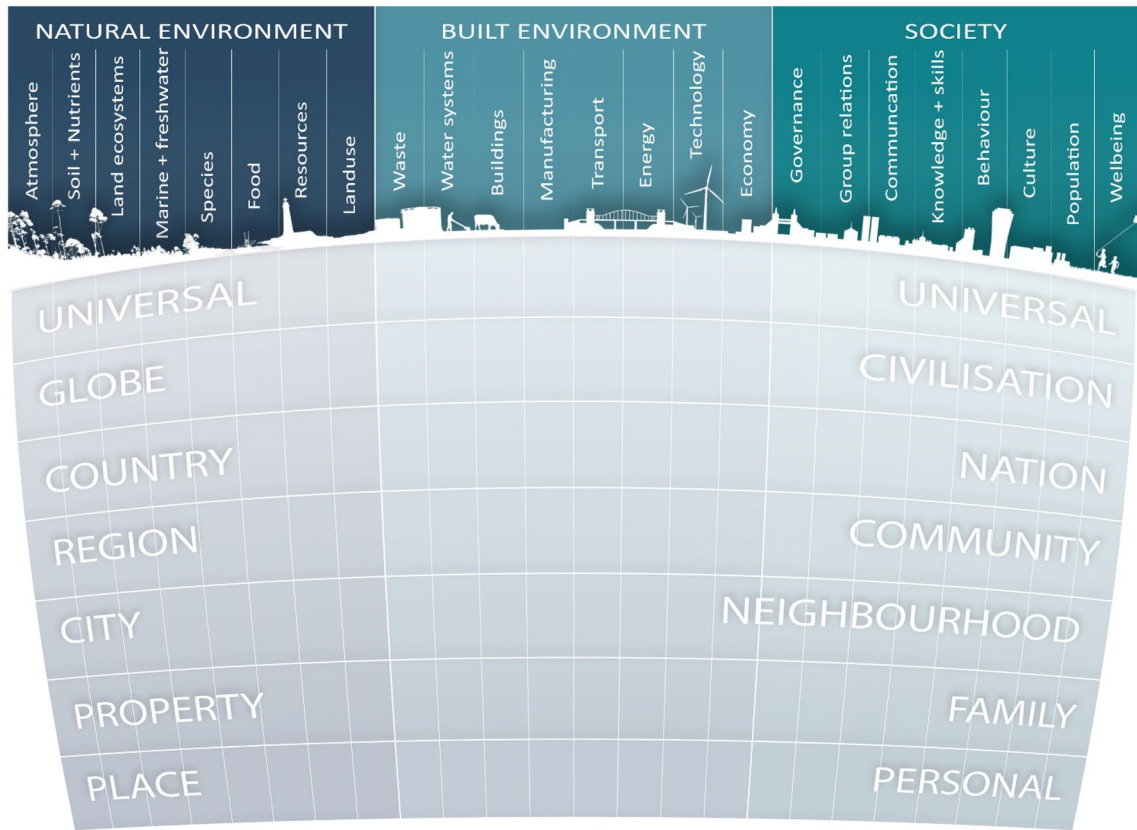
**b) Concept** - system components  
Each icon represents a noun - a concept added by users. These could be general (e.g. forest) or specific (e.g. rate of nutrient cycling).

**c) Link** - relationships in a system  
Each link represents a verb - a relationship between two concepts. These are coded to represent types of relationship e.g. increases (+++), decreases (---), causes. These links can be existing or potential and could unfold across a defined length of time.  
Each link can be tagged with a link type e.g. Ecosystem Services.

**d) Insight** - Emergent properties, guiding principles and groups  
These zones prompt users to consider higher-order phenomenon such as 'Sustainability', 'Resilience' or Sustainable Development Goals.

**e) Self - enhancing agency**  
Footprint: the load our consumption puts on the biosphere (including diet, housing, transport, and lifestyle/family).  
Handprint: the broader (typically positive) impacts of our contributions to the environment and society.

**Fig. 2** Overview of MetaMAP framework identifying five of the six core components: **a** Landscape of ideas, **b** Concepts, **c** Links, **d** Insight, and **e** the Self



**Fig. 3** The Landscape of ideas – an organisational framework for organising concepts according to their geographic (left) or social (right) scale (y-axis), and category within our social-ecological system (x-axis)

example, subnational governments (state and local) may support or undermine SDGs through land use policy and development approvals. Businesses at any scale influence social and environmental SDGs through their use of resources, their employment practices, and their supply chains. Even at a community or individual scale, people contribute to or

undermine SDGs through their consumption, civic engagement, and how they direct their work efforts. Aligning these numerous smaller scale actions in support of the SDGs can substantially advance the SDG agenda. Doing so requires better ways of understanding cross-scale impacts and directing them strategically, hence this framework.

**Fig. 4** Several example concepts located by users on the Landscape according to their scale and category, relevant to their context of use





**Fig. 5** Links show how one concept influences another. In this example, forest regeneration increases carbon absorption which in turn reduces global warming

#### b) *Concepts*

– In MetaMAP, *concepts* describe nouns—parts of a sustainability system being investigated. Users can represent concepts as words or icons and position them in cells on the ‘Landscape of ideas’ according to their scale and category (Fig. 4). Concepts in MetaMAP may describe abstract or tangible topics, and may be general (e.g., ‘forest’) or specific (e.g., ‘The Daintree Rainforest’) according to users’ needs in a particular circumstance. Concepts can relate to objective issues such as ‘solar power plant’ or subjective issues such as ‘perception of climate change’.

#### c) *Links*

– Links describe verbs—influences that one concept has on another. They are represented by lines and arrows linking two or more *concepts*. For example, Fig. 5 describes how forest regeneration increases carbon absorption which in turn reduces global warming. Users can describe different types of relationships using different types of lines and arrows. Common examples include increases (+++), and decreases (---) (Fig. 5). Links can be one or two directional represented with one or two arrow ends. MetaMAP is a flexible system and new types of *link* can be established by the user community.



**Fig. 6** Space to identify emergent properties and guiding principles on the right of the landscape. Several prominent examples are shown including ‘resilience’, ‘synergy’, and ‘Planetary Boundaries’

#### d) *Insight*

– containing groups, emergent properties, and guiding principles within MetaMAP

Understanding the complexity of sustainability challenges demands insight into big picture issues which emerge as parts of the system interact over time. Emergent properties are higher-order phenomenon arising from the interactions of other factors. In the context of MetaMAP, this includes important phenomena such as ‘feedback loops’ (Gunderson 2001), ‘synergy’ (Strackan 2009; Reynolds and Holwell 2010) and ‘resilience’ (Folke 2006). Many of these properties are common among different sustainability challenges. Having a unique place in MetaMAP prompts users to consider them explicitly and discuss them independently of any particular system. In MetaMAP, ‘emergent properties’ sits outside and to the right of the landscape of ideas (Fig. 6).



MetaMAP also contains a dedicated place for a different type of higher-order concept: *guiding principles*. These are aspirational principles which help to guide the design of social-ecological systems towards more sustainable outcomes. They can be developed by users as relevant to their context and needs. While there is overlap between emergent properties and guiding principles, the first is primarily descriptive and objective, while the latter is subjective and aspirational.

Other types of insight can be represented through groups—sets of related concepts and links. Breaking up complex concept maps into manageable chunks makes them easier to understand and communicate. Groups are not mutually exclusive, rather they can overlap or sit within other groups. Together, these approaches of representing insights in MetaMAP are ways of notating a concept map to aid deeper understanding.

- e) *Self*—including user dashboard, footprint and handprint, and user profile

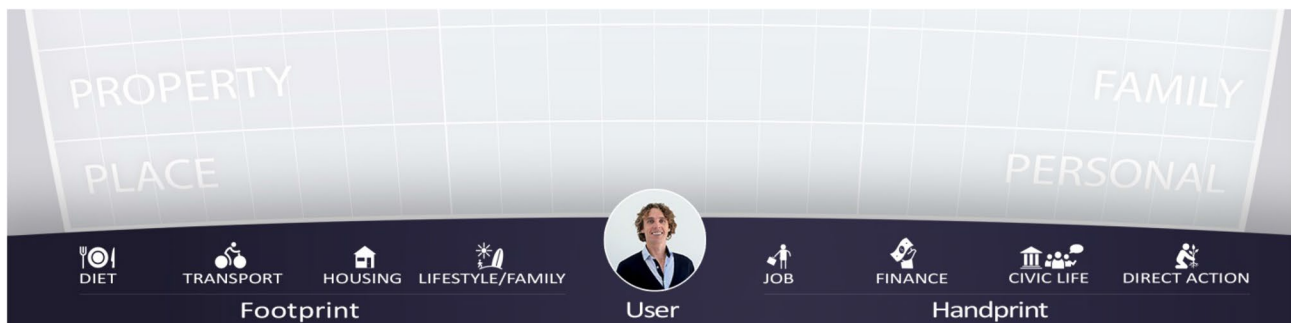
Understanding one's place in society and nature is important for contributing to the SDGs but is often neglected by existing frameworks. It is one thing to understand a system objectively, but another to understand where you have greatest leverage in changing it. MetaMAP connects a user personally to the system being studied with the *user dashboard* section along the bottom (Fig. 7). It includes two major components: *footprint* on the left and *handprint* on the right. Footprint, adapted from the Ecological Footprint methodology, relates to the burden that our consumption puts on the biosphere (Wackernagel and Rees 1996). This includes *diet, housing, transport, and lifestyle/family*. Handprint describes the broader impacts of our contributions to the environment and society, typically in a positive light (Biemer et al. 2013). This includes one's *job* (how we contribute through our work),

*finance* (the actions we help to fund), *civic life* (the ways we engage in politics and community), and *direct action* (positive actions of immediate benefit). Users can link their *footprint* and *handprint* to the parts of the social-ecological system they affect. For example, users may link the meat in their diet to cattle farming, which may in turn be linked to forest cover change and methane emissions, then to SDG 13 Climate Action and SDG 15 Life on Land. This shows one path of impact across scales from personal diet choices to the Earth's climate and the SDGs. In the proposed digital platform, the user's profile image is front and centre, emphasising a first-person perspective. This is similar to a vehicle's dashboard and to many intuitive computer game interfaces. The dashboard shown is tailored to use by individuals and small groups, but can be tailored to suit the more complex footprints of organisations or nations. Users determine which perspective is most useful for which purpose. The dashboard helps to shift the user's perspective of themselves from outside observers to active agents.

- f) *Guided processes*

Guided processes can help unfamiliar users to apply MetaMAP more effectively to sustainability challenges. They can be developed for different purposes and user groups. The example in Text box 1 is based on design thinking (Rodgers and Yee 2014), Soft Systems Methodology (Checkland and Poulter 2010) and group facilitation approaches. This was applied in collaborative workshops to test and develop MetaMAP (Fig. 8). Pursuing a process more fluidly can provide space for intuition and critical judgement which can lead to better outcomes. After each stage, users should reflect on and refine previous steps. *What have we learnt? How should it develop?*

This collaborative process and consistent framework can help to pinpoint where different participants' perspectives



**Fig. 7** User dashboard identifying different parts of the user's impacts on the social-ecological system. These are grouped as footprint on the left (the demand we place on the biosphere) and handprint on the

right (the good we do for the environment and society). In the proposed digital platform, the central image and name is linked to the user's profile, emphasising a first-person perspective

align and differ. Like all collaborative processes, this has the potential to provoke conflict, but also provides a common ground upon which to negotiate these differences. One purpose of MetaMAP is to help diverse users create a higher common understanding of an issue, within which their

unique perspectives may be situated. How users respond to this is at the discretion of the user, depending on their preferences and circumstances. Experienced facilitation of collaborative model building processes can help users to navigate these differences productively.

### **Text Box 1: Example guided process for MetaMAP**

#### **STEP 1) Map**

- Based on your existing experience, add key issues to the landscape and position them according to their scale and category.
- Link these issues to related issues to describe relationships among them. Consider if these relationships describe causes (where one factor increases or decreases another), authority (where a stakeholder manages an issue), or other factors, and describe this with notes or different types of lines.
- Add important steps along the way. The detail required will depend on context, so use your judgement, then revise as needed.
- Consider how other categories might relate to the existing concepts. Especially consider empty realms. e.g. if the map focuses on the natural environment, consider how society is related.

^ Reflect and refine all previous steps.

#### **STEP 2) Collaborate**

Seek input from others with different experience and perspectives.

- Add concepts and links representing others' perspectives.
  - Have collaborators critique the existing map.
- (Where expertise is limited, try to take on another perspective yourself to develop the map. e.g. 'If I was an ecologist, what would I notice differently?')

^ Reflect and refine

#### **STEP 3) Insight and SDGs**

Consider the whole system. What patterns do you notice?

- Add groups, emergent properties and guiding principles.
- Note where your system contributes to or undermines SDGs.

^ Reflect and refine

#### **STEP 4) Strategise**

Consider potential conflict and opportunities for additional benefits within your system.

- Note synergy and trade-offs.
- Where are the points of leverage within the system? Where are the opportunities to drive change?

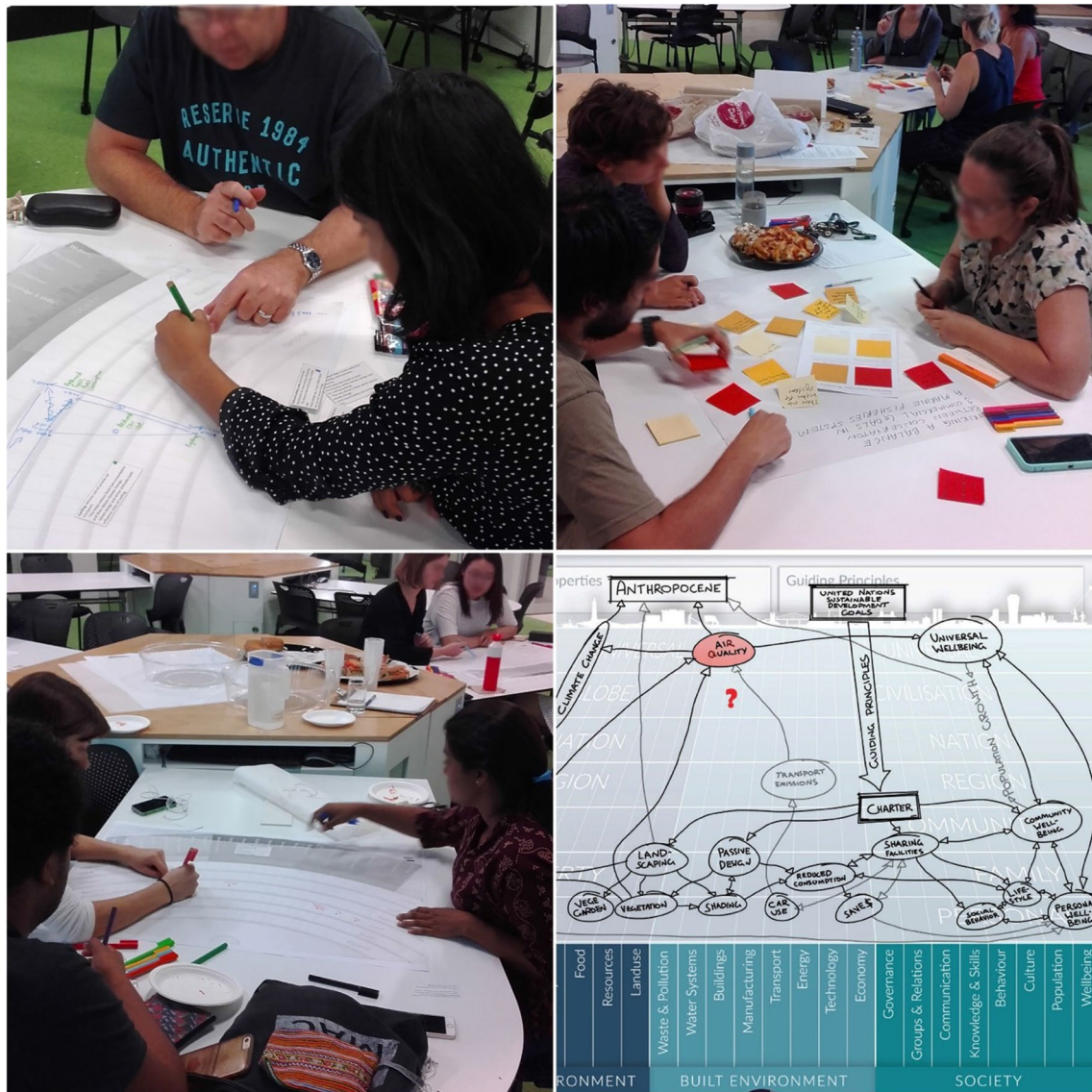
^ Reflect and refine

#### **STEP 5) Act**

Consider yourself within the system.

- Link components of your footprint to parts of the system they affect, and then to the SDGs.
- Link your handprint to the system. Where can you help shift the system towards greater sustainability? Who will you have to work with to succeed?

^ Reflect and refine



**Fig. 8** Collaborative workshops applying and developing MetaMAP prototypes using the guided process

## Demonstrating MetaMAP via an Ecovillage case study

### Case study background

MetaMAP can be applied to a wide diversity of sustainability challenges and contexts. The following case study demonstrates MetaMAP and its application in more detail. In this case study, an interdisciplinary team of investigators collaborate to understand how a residential development affects society, the environment, and the SDGs, and how they can make it more sustainable. This case study is based on studies of Currumbin Ecovillage, Gold Coast, Australia, conducted by over 30 Master of Architecture students as

part of the process of designing MetaMAP (Maher et al. 2018a, b). This narrative is simplified for explanation, but it serves to introduce MetaMAP concepts and demonstrate how it supports more effective thinking, communication, and collaboration.

Currumbin Ecovillage is a sustainably designed community in Australia (Fig. 9). It was developed in 2006 and is now home to 450 people and diverse wildlife (O'Callaghan et al. 2012). It has received numerous awards including The World's Best Environmental Development 2008 (Landmatters 2013). The Ecovillage provides a suitable focus for study as it engages with a wide diversity of sustainability issues and strategies including environmental, cultural, governance, technology, infrastructure, and building design. The case study below relates to the water and waste



**Fig. 9** Contextual photograph of Currumbin Ecovillage – an Australian freehold community in a rural subtropical landscape pursuing sustainable lifestyles (Source: Landmatters 2013 ©)

treatment system of the Ecovillage and expands to include a wide range of issues. The reader is encouraged to consider what *you* would add to the investigation based on your own experience and how that might enrich the understanding and actions of others.

### Case study narrative: using MetaMAP to understand an Ecovillage

Investigators begin using MetaMAP to describe some of the core sustainability issues in the Ecovillage and how they relate across scales. A landscape manager first describes how the community’s water treatment plant (a) generated an abundance of water (b) which was used, in part, to aid the regeneration of native forests in the Ecovillage (Fig. 10). An ecologist adds that the growing forests (c) absorb carbon from the atmosphere (d), which reduces global warming (e). This contributes to SDG 13: Climate Action. In the workshop, concept maps were drawn by hand and using sticky notes, and the figures in this paper are redrawn digitally for ease of reading. The figures within this case study are included in Appendix A as full-page images, and the base framework is in Appendix B, which is suitable for printing.

Each link identifies the type of relationship between concepts, in this case, increasing (+) and decreasing (-). The overall path from the foreground to the horizon shows vividly how a small-scale initiative (water treatment plant a) can contribute to global outcomes (global warming e).

Next, an architect notices that the rapidly growing forest (c) in the Ecovillage cooled the local microclimate (f), which reduced the demand for cooling in nearby homes (g). They add hand-written notes to ‘tag’ this process as an ecosystem service – either provisioning, regulating, supporting or cultural (Bennett et al. 2009; Abson et al. 2014) (Fig. 11). This offers an avenue for ecosystem service specialists to provide input into a wide variety of sustainability issues where they may otherwise be overlooked. In other case studies, the MetaMAP framework helped participants to identify ecosystem services related to their own work, even when they had not heard of the concept before (Maher et al. 2018a, b). Insights from this part of the workshop identified that participants envisioned its application in a digital tool where they could tag the model they were building with additional detail. Proposed digital enhancements like this are described below in Sect. 4.4.

### Groups (insight)

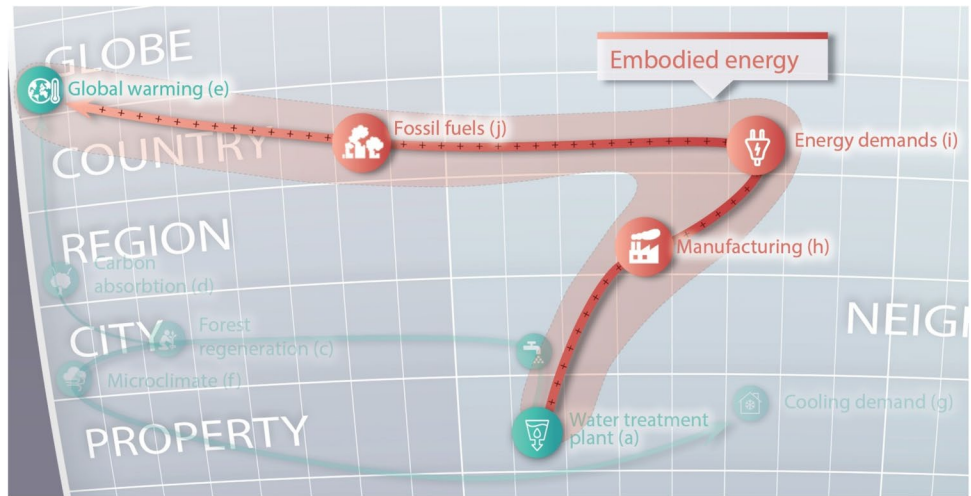
An industrial ecologist takes a different perspective and considers the process of manufacturing the water treatment plant. They describe a chain of impact of how the manufacturing process (h) consumed energy (i) which was produced from fossil fuels (j) which increased global warming (e) (Fig. 12). The investigators group and label it as ‘embodied energy’, so that it can be discussed

**Fig. 10** A first path of inquiry showing one way in which the Ecovillage water treatment plant is helping residents to regenerate native forest and reduce global warming. Links coded with different line types to identify how one concept relates to another, in this case increasing (+) and decreasing (–)



**Fig. 11** In this example, the regenerating forest cools the local microclimate, which reduces the demand for cooling in nearby homes. This link has been coded as a regulating ecosystem service, connecting it with a broader body of knowledge and expertise

**Fig. 12** The users describe how manufacturing the treatment plant consumes energy, which is sourced from fossil fuels, thus driving global warming. They label this group as ‘embodied energy’



independently. This grouping helps to streamline the concept map which aids insight and communication. It also allows a common group of issues to be saved and used in other projects.

### Emergent properties and trade-offs

The Ecovillage investigators note that the addition of embodied energy highlighted a trade-off in addressing SDGs: on one hand using treated water to regenerate forests absorbed carbon dioxide, reducing global warming. On the other hand, the energy demands of manufacturing the treatment plant increased global warming (Fig. 13). Investigators identify this trade-off as an emergent property of the system for further deliberation. Identifying and

navigating trade-offs like these are important for achieving SDGs in an integrated way (Rodríguez et al. 2006). Again, the presence of this category in MetaMAP prompted users to consider trade-offs explicitly.

### Suggestions and critique

MetaMAP allows users to make suggestions and critique concept maps. A long-term Ecovillage resident suggests that the treatment plant (a) caused residents to reduce their use of toxic cleaning agents (k) – and hence shifted community behaviour (Fig. 14). This broad collaboration across disciplines and stakeholders is important for understanding sustainability challenges holistically and developing more integrated solutions.

**Fig. 13** MetaMAP users identify a trade-off as the Ecovillage water treatment plant both increases and reduces global warming

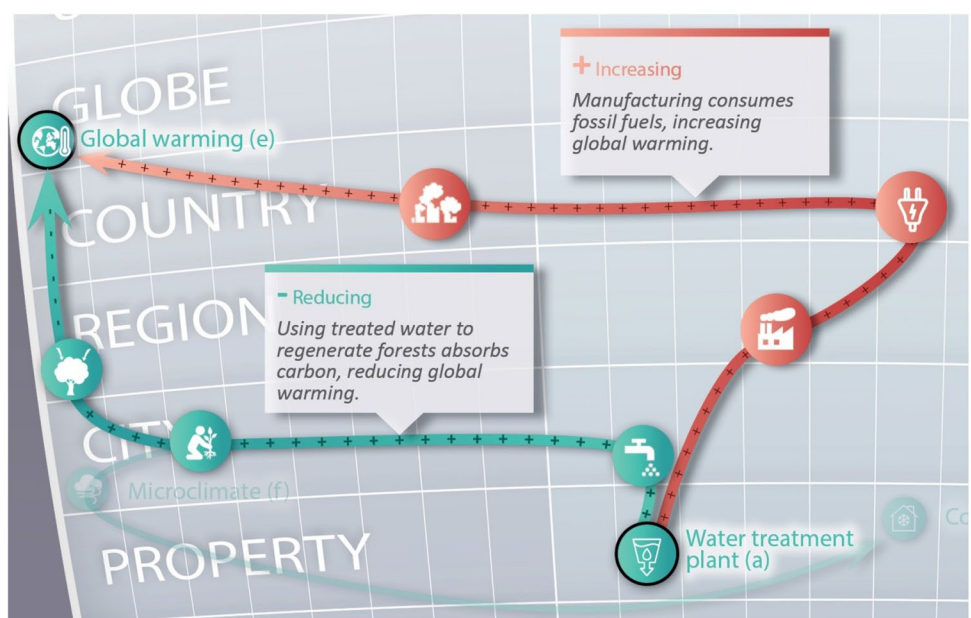




Fig. 14 A local provides comment on the MetaMAP in progress, noting how the new treatment plant helped to change people’s behaviour

**Linking to the Sustainable Development Goals (SDGs)**

Having developed a somewhat comprehensive map of key components of their system, the investigators consider how the Ecovillage related to the UN SDGs which were now added to their concept map. This helps them to identify which SDGs the Ecovillage helped to achieve and how. In

this case, SDGs 6, 12, 13, 14 and 15 were seen to benefit from the initiative being investigated (Fig. 15). Linking the Ecovillage with the SDGs helped connect the investigators’ work at a neighbourhood scale to the global goals. These cross-scale links are critical for achieving SDGs as they unify and empower many more actors and resources to help achieve them.

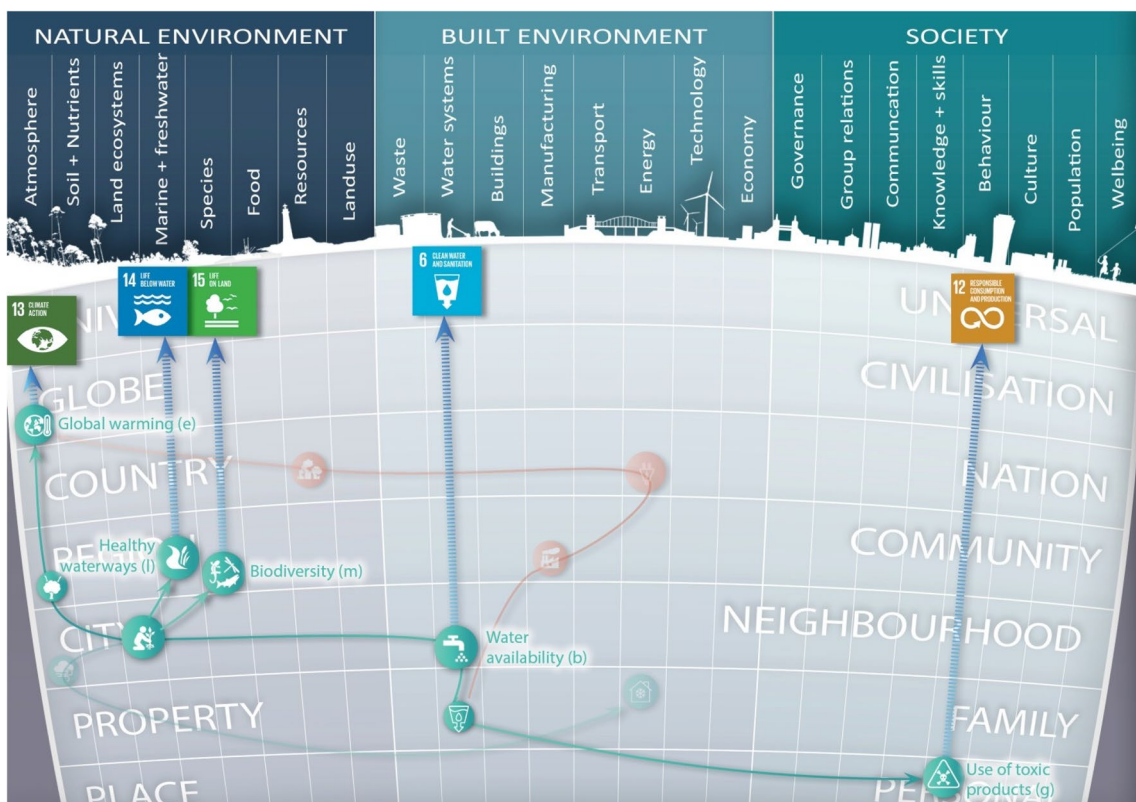
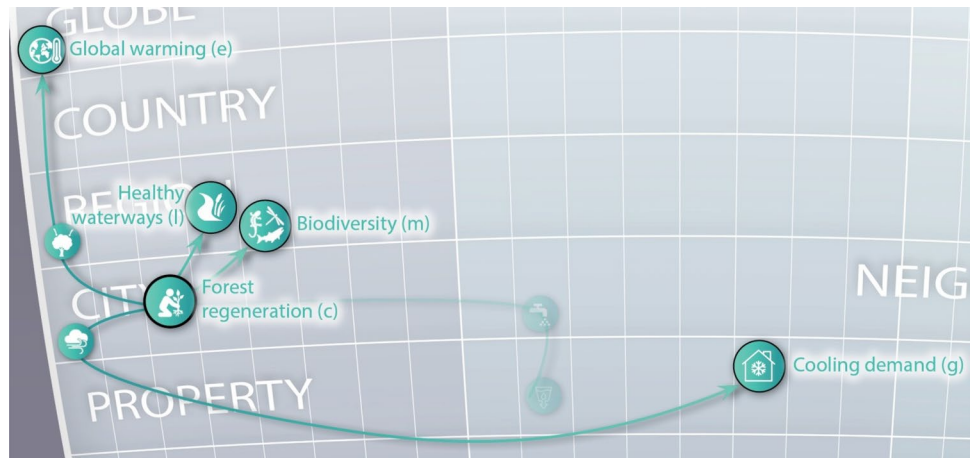


Fig. 15 MetaMAP showing how the ecovillage treatment plant helps to support several Sustainable Development Goals

**Fig. 16** MetaMAP helped users to identify an important synergy in the social-ecological system: regenerating the native forest provides many complementary benefits

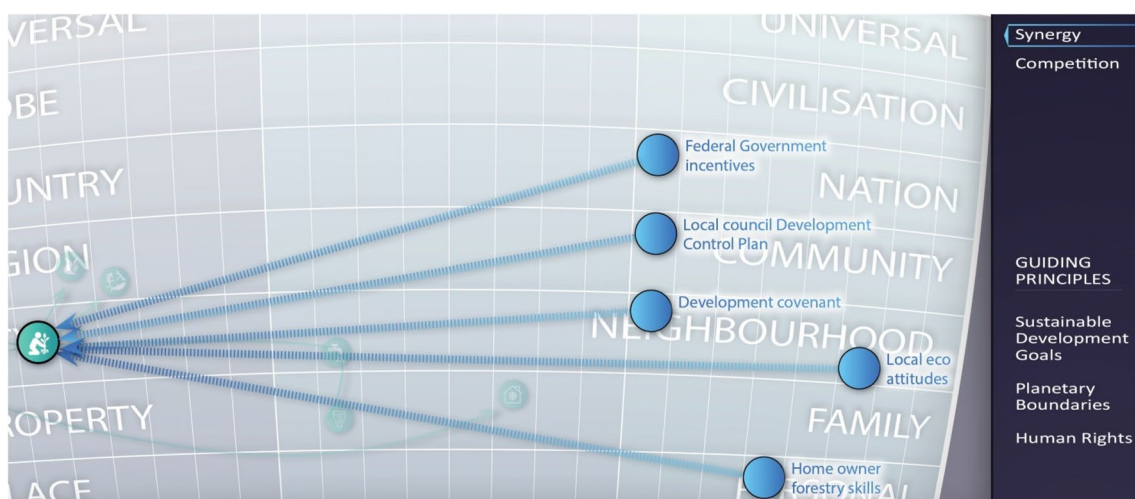


## Synergy

Considering the multiple benefits stemming from community forest regeneration, the investigators recorded this as a synergy—a type of emergent property in which one action can deliver multiple benefits (Fig. 16). They note that ‘Rapid forest regeneration in the ecovillage improves biodiversity (m), reduces global warming (e), supports healthy waterways (l), and reduces cooling demand of homes (g)’. Identifying synergy is critical for designing effective solutions for wicked problems (Sterling 2009), which are common to SDGs. By achieving multiple goals simultaneously, synergy can also help to find common ground and build wider support for an initiative (Hall et al. 2017). In this case, people interested in either reversing global warming,

improving local biodiversity, improving water quality of the local swimming hole, living in cooler homes, or saving on energy bills each have a ‘vested interest’ in supporting forest regeneration in the Ecovillage.

Having identified local forest regeneration as a point of leverage over multiple sustainability goals, the investigators now seek complementary ways to improve it. They identify multiple possible paths for increasing forest regeneration including three levels of governance, local attitudes to the natural environment, and the regeneration skills of members of the community (Fig. 17). In doing so, the focus of the investigation shifts from a water treatment plant to forest regeneration. The investigators’ motives also shift from understanding the system to proactively seeking strategies to change it. The investigators become strategists.



**Fig. 17** Investigators identify five compounding ways of supporting forest regeneration relating to social power (three tiers of governance), values (local attitudes to the environment), and knowledge (improving their own forestry skills)



## A first person perspective

Understanding potential strategies is a useful start but has limited value if those who recognise them have no means to implement them. This is a common limit of research on ‘leverage points’ (Meadows 1997; Abson et al. 2017) when it does not consider the actors’ capacity. The user dashboard at the bottom of MetaMAP helps users to see connections between their actions and the system they are investigating. In this case, an Ecovillage resident identifies four concrete actions that they could take to support the regeneration of the forest in their community: ensure their house has a small physical footprint to leave more space for forest on their own property (n); learn and practice more effective forest regeneration methods (o); lobby local council to implement supportive policy (p); and promote the idea in their local community (q) (Fig. 18). Other users could link themselves to the same system in different ways, depending on their own unique opportunities, interests, and capacity. Overlaying different users’ handprints (using transparent paper or future digital tools) can help to identify synergies among different actors. In this way, MetaMAP becomes a framework for collaborative action.

The focus of the study has now progressed further: what began as a general investigation has evolved into a strategy tailored to specific actors and points of leverage. Throughout this process, MetaMAP helped users to transform their perspective from outside observers to active participants within the system, increasing their agency. In this case, the first-person perspective in MetaMAP—the self—represented a specific individual, but it could equally represent a particular family, business, community group, or organisation. The dashboard can be tailored to the group’s more complex footprint.

## Digital enhancements

Developing MetaMAP into a digital platform (MetaMAP-Digital) has the potential to add several significant benefits (Fig. 19). This digital environment could support greater application of design thinking to sustainability challenges, and foster wider collaboration; it also possesses capacity to become a global knowledge-sharing platform. In addition to its primary role as a usable decision-support tool, the analogue version of MetaMAP described in this paper also acts as a prototype for the proposed digital platform. In the proposed digital platform, users can add content to each concept including descriptions, images, and associated research. Diagrams can help to explain complex or specialist concepts to a wider audience, increasing their value for decision-making. Images can help to make abstract concepts felt vividly, which is important for connecting knowledge with ethics, and ideas to action (Blewitt 2009; Vervoort et al. 2014). These types of associated content can help users to understand a concept in the context of the broader social-ecological system. Once familiar with a particular concept, users can rely on icons to represent it to reduce visual clutter and mental exertion (Sweller et al. 1998; Dunlosky et al. 2013), and facilitate big-picture thinking (Rodgers and Yee 2014). This is similar to architectural iconography and design tools (e.g., Autodesk Revit or ArchiCAD).

In the proposed digital version, links between concepts can be prompted automatically based on previous entries. Content can also be attached to web links. In addition, users can specify the degree of confidence of a link ranging from ‘speculative’ to ‘confirmed’ (Fig. 20). When working with complex and uncertain circumstances which are common in sustainability, it is important to embrace intuition and insight even in the absence of evidence (de Bono 1970; Moloney

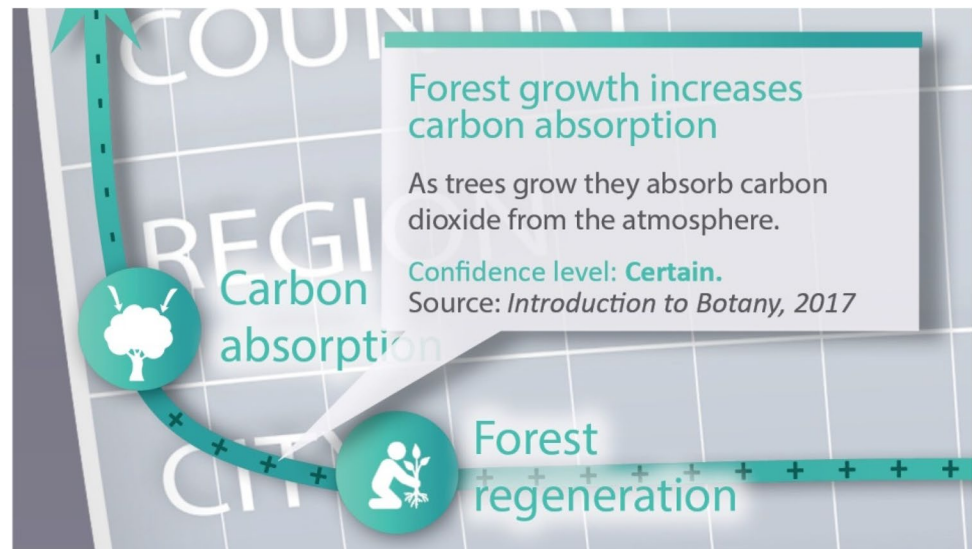


**Fig. 18** A community member uses MetaMAP to identify four achievable ways of supporting forest regeneration in the Ecovillage



**Fig. 19** Representation of MetaMAP applied in an interactive digital platform (MetaMAP-Digital) and accessible via a tablet

**Fig. 20** In the proposed digital platform, each link can have a description, related content, and express a level of confidence ranging from tentative to certain. Specifying higher levels requires evidence



2015). Intuitive leaps help to challenge assumptions, develop new approaches and identify paths for further investigation. However, it is also important to differentiate between speculation and knowledge based on evidence. MetaMAP users can attach peer-reviewed research as evidence when specifying a link with a high degree of confidence. For example, Fig. 20 describes high confidence that forest growth lowers atmospheric carbon dioxide and cites a book as evidence. A digital platform could automatically recommend concepts and links, based on previous user input. Beyond that, we speculate that such a platform could support the collaborative building of an ecosystem of knowledge on sustainability along the lines of Wikipedia or OpenStreetMap (<https://www.openstreetmap.org/>). In this case, users could contribute knowledge to the system by adding concepts and links which represent articles or projects. MetaMAP could then act as a visual interface to help navigate the ecosystem of knowledge the way one uses a GPS map to navigate a city.

It should be noted that each version of MetaMAP, whether digital or paper-based, is a unique artifact with some distinct characteristics. While the analogue version presented here provides a prototype of a digital version, it is not possible or helpful to translate it directly from one medium to another. One important distinction among these two media is the support dialogue among participants. Digital platforms can support this dialogue, but it takes on a different character to in-person engagement with different advantages (e.g., recording, time to consider, broader engagement across borders) and disadvantages (e.g., slower feedback loops, interpersonal relationships). Development of MetaMAP-Digital must consider these differences and their impacts on thinking and decision-making for sustainability.

Time is central to sustainability (Rodríguez et al. 2006) but it can be difficult to communicate and envision. MetaMAP allows users to notate a link with the time it takes to unfold ranging from immediate, to centuries. This can help to expand the scope of consideration rather than selecting one time horizon (e.g., 30 years) and neglecting processes which extend beyond it. It also helps users to consider trade-offs between short- and long-term issues, critical for inter-generational equality.

## Discussion

### Understanding MetaMAP from different disciplinary perspectives

To gain a deeper insight into what MetaMAP provides and demonstrate its validity, this discussion takes a pluralist perspective by examining MetaMAP from several disciplinary

perspectives, each emphasising different attributes. What is MetaMAP? It depends on who you ask. While theory can reside entirely within the world view of one discipline, a real-world object is open to interpretation from anyone who cares to look. MetaMAP encompasses:

- *Sustainability science* ...a conceptual meta-framework which synthesises multiple ways of understanding sustainability issues.
- *Systems thinking* ...a framework for building conceptual models of social-ecological systems and organising them consistently to aid comparison, see emergent properties and visualise cross-scale interactions. This can provide a basis for quantitative models.
- *Design* ...a set of graphical tools and processes which help users to see synergies, conflicts, and new opportunities, and to test ideas when designing sustainability initiatives.
- *Sustainability communication* ...a communication tool which applies a common visual language for communicating complex sustainability issues across disciplinary, institutional, and social barriers.
- *Transdisciplinary research* ...a framework for synthesising different disciplinary perspectives on a sustainability challenge into a common understanding represented with a collective mental map.
- *Philosophy* ...a way of expanding one's perception of sustainability challenges to encompass a broader range of issues and possibilities, and how they relate.
- *Cognitive psychology* ...a tool for reducing cognitive load by aiding memory and pattern recognition, helping us to apply our intelligence to solving problems more efficiently, effectively, and creatively.
- *Strategy* ...a system for assisting leading thinking on sustainability to propagate further throughout society. It does this by making it easier for a wider audience to apply leading sustainability concepts in practice.

The lead designer (author) drew on these perspectives empathetically at different times while designing MetaMAP (Maher et al. 2018a, b). This helped to identify opportunities to add value and integrate different approaches into the framework/tool/process.

The MetaMAP framework is highly inclusive, incorporating elements of many different concepts and conceptual frameworks. Several of these are highlighted in Fig. 21 and Table 2 below. Somewhat surprisingly, this demonstrates for the first time that many of these different frameworks of sustainability are actually compatible—they can be synthesised into a new, higher-order structure. Research into



Fig. 21 MetaMAP framework identifying some of the prominent theory it synthesises

**Table 2** Concepts and frameworks incorporated into MetaMAP

Concepts and conceptual frameworks incorporated into MetaMAP	How it is incorporated	Value it provides for users
Social-ecological systems (Ostrom 2009)	Concept maps co-created by users represent social-ecological systems. The categories and realms describe components of the social-ecological system. Guided processes highlight leverage points	Categories and realms prompt users to expand the boundaries of their mental models. Focus of inquiry can shift from components to relationships among them and across scales, to higher-order emergent properties
Integral theory (Brown 2007)	The guided process supports users to include objective and subjective dimensions to their analysis. The dashboard provides a first-person perspective on the broader system	Combining objective and subjective engagement with individual and collective issues facilitates a more comprehensive understanding of the focal challenges. It also supports broader engagement and knowledge synthesis among diverse stakeholders
Sustainable Development Goals	The SDGs can be located on MetaMAP (Fig. 15) and connected with components of the system under investigation	Connecting multiple SDGs to a system helps to identify synergies and trade-offs among them. It also supports decision-makers to identify how they can contribute to the SDGs across scales
Planetary Boundaries (Rockström et al. 2009)	The Planetary Boundaries can be located on MetaMAP similarly to the SDGs	Linking a system to the Planetary Boundaries helps to identify which immediate and distant factors may contribute to overstepping boundaries
Ecosystem services (Abson et al. 2014)	Links between components of the natural environment and society can be ‘tagged’ as Ecosystem services (Fig. 11)	Identifying Ecosystem services within a system links it with a broader body of knowledge and expertise, and established frameworks for analysing and managing them
Ecological Footprint (Wackernagel and Rees 1996; Ewing and Kitzes 2008)	Components of the Ecological Footprint are incorporated into the user dashboard. They can be tailored to individuals, organisations, or municipalities	MetaMAP prompts users to connect systems ‘out there’ with one’s ecological footprint to build agency
Ecological Handprint (Biemer et al. 2013)	Components of the Ecological Handprint are incorporated into the user dashboard	Including the Handprint framework prompts users to maintain a positive and proactive outlook on sustainability interventions which is often lacking in the field

the synthesis of these frameworks is underway and will be reported in an upcoming publication.

#### Four primary lenses

MetaMAP helps users to put leading sustainability theory from several different disciplines into practise. These perspectives include concepts and approaches from Systems thinking, Design thinking, Cognitive Psychology, and Integral theory. These “frames of reference help us to see the same world differently” (Sousanis 2015), opening up new opportunities for achieving SDGs synergistically. This discussion briefly introduces several important concepts, recapping their value for sustainability and describing how MetaMAP helps users to apply them in practice.

#### A design thinking perspective

Design thinking approaches excel at addressing ‘wicked’ problems which are complex, contested, and open to multiple interpretations and value judgements (Glanville 2007; Weber and Khademian 2008; Harris et al. 2010). Achieving SDGs involves similar challenges, so design approaches hold

much value (Maher et al. 2018a, b). Design thinking involves developing a holistic understanding of the problem and its context then using intuition to generate multiple options and critical judgement to select and refine them (Maher et al. 2018a, b). Design ideas are usually represented visually and developed through multiple iterations (Laseau 2001; Elmansy 2017).

MetaMAP supports design thinking in many ways from its structure and application to how it is represented visually. Table 3 identifies five design principles of value to achieving sustainability goals and summarises the ways in which MetaMAP helps users to apply them. In brief, MetaMAP’s broad and inclusive framework helps users to build a holistic understanding by integrating many different perspectives. Concepts and links can be added intuitively (and tagged with an appropriately low level of confidence where evidence is limited). Multiple options can be explored and critiqued by specialists with expert knowledge. Seeing details in relation to the whole is essential for designing well-integrated sustainability initiatives, fit for their social-ecological context. Building on synergies and managing trade-offs are also critical for design thinking but challenging to represent. The case study demonstrated how MetaMAP makes them visually explicit and orchestrates the entire process through an

interactive visual interface, resembling architectural design tools. Proposed interventions (or designs) in a system can be developed through immediate visual feedback to the user (similar to architectural design tools), and also by facilitating critique by others.

### A systems thinking perspective

Achieving SDGs involves complex relationships between different aspects of society and nature. Systems thinking (Ackoff 1994; Strackan 2009), especially social-ecological systems (Anderies et al. 2004; Ostrom 2009; Partelow 2015; Maher 2017), is an approach for understanding and managing these relationships explicitly. MetaMAP helps unfamiliar users to apply many systems techniques in their thinking, including nodes and links, feedback loops, emergent properties, and leverage points. This approach of representing concepts and relations is based on Soft Systems Methodology—a highly flexible “action-oriented process of inquiry into problematic situations” (Checkland and Poulter 2010) using conceptual models. However, most systems models are represented as nodes and links floating in empty space, so any two versions of the same model will look very different. MetaMAP provides a consistent but flexible framework to organise systems models, allowing models to be compared rapidly. Unlike unstructured systems, MetaMAP also helps users to see the ‘shape’ of the whole system, which highlights areas of focus or neglect. This framework also highlights cross-scale interactions which are important for achieving SDGs but notoriously difficult to comprehend and communicate.

All systems approaches involve making judgments about what is important and what to exclude. Without proper critique, assumptions can be reinforced, and neglected parties remain so. ‘Systematic boundary critique’ involves carefully considering where we draw boundaries around areas of concern and what we exclude (Ulrich 1983). Good decision-making for sustainability must consider both “the specific system to be improved (and) the context of other interests that may be affected” (Ulrich and Reynolds 2010). The categories in MetaMAP prompt users to consider a wide range of issues which extends beyond the typical scope of any one discipline or profession. Using MetaMAP to collaborate on interdisciplinary projects (such as the Ecovillage case study) promotes systematic boundary critique as each new contribution helps to critique those that came before. In a proposed digital environment, the addition of each new concept, link or group can be critiqued and discussed with a wide user group across online networks. Further, MetaMAP can be used to help critique existing proposals or analyses. For example, mapping an SDG initiative developed by traditional economists may reveal that important ecological systems have been excluded. MetaMAP reveals when a whole realm (e.g., the natural environment) is absent from a concept map. In total, the structured framework and guided processes help uninitiated users to apply important systems concepts to achieve sustainability goals.

### A cognitive psychology perspective

Understanding complex relationships between society and nature and how these relationships vary across time and space is a challenging mental exercise. Weighing up multiple

**Table 3** Design principles, examples from the design of MetaMAP, and ways that MetaMAP helps users to apply the principle in practice

Design principle	Ways that MetaMAP helps users to apply each principle
Broad problem framing supporting multiple goals	Incorporating many disciplinary perspectives and frameworks The scales and categories of MetaMAP’s framework expands users’ conception of sustainability challenges Prompting and facilitating links to several SDGs Guided processes include layers of reflection and reframing
Maximise synergy, minimise compromise	Guided processes prompt user groups to actively seek synergy Points of convergence in concept maps highlight potential synergy MetaMAP framework incorporates emergent properties
Integrating diverse perspectives	MetaMAP framework synthesises divergent perspectives Facilitating identification and visualisation of cross-scale interactions Users build concept maps by integrating ideas Guided process supports collaboration
Thinking visually	Graphical interface stimulates mental visualisation Visual metaphors aid rapid understanding Application of graphic language (colour-coding, line types, position, relationship among parts) reduces demand on working memory to understand complex issues
Multiple feedback loops	Visuals aid critical reflection on concept maps Guided processes include repeated reflection Interdisciplinary teams with different perspectives

possible interventions, each from several different perspectives is yet more difficult. MetaMAP's visual interface supports these mental processes and makes it easier to apply complex thinking to understand and address sustainability challenges. Metaphorically, many sustainability practitioners are playing chess without a board. MetaMAP provides the board.

The visual interface is understood more rapidly and retained in the memory longer than written words alone (Dunlosky et al. 2013). Icons provide a common language accessible to people with different professional and cultural backgrounds. The organisational framework helps to compare options and immediately see relationships which reach across scales. Together, these features reduce cognitive load, freeing more working memory for solving problems (Hacker et al. 1998; Sweller et al. 1998).

Users found that, by representing ideas visually, MetaMAP allows users to *see* how they *think*. This 'metacognition' helps users to critique and develop their own thinking (Hacker et al. 1998). Similar visual thinking approaches are used extensively to develop ideas iteratively and self-reflect on both the proposed outcome and the process through which it is achieved. These visual approaches have been used in design (Suwa et al. 2001; Maher et al. 2018a, b; Kernbach 2019; Mouhebati et al. 2019; Ware 2021), systems approaches for managing change (Ulrich and Reynolds 2010) and sustainability (Sevaldson 2011; Widener et al. 2016; Cortes Arevalo et al. 2020). Dual process theory describes two primary modes of thinking: intuition which is fast, unconscious and associative; and reasoning which is slow, deliberate and rule-based (Evans and Frankish 2009). Both are important for creating new solutions to complex problems, but the cultures of different disciplines and professions often favour one at the expense of the other (Becher and Trowler 1989; Scheffer 2014). MetaMAP brings these two modes together. Intuition is supported by tools for perceiving and communicating big-picture insight (Fig. 6, Fig. 13). Reason is supported by tools for critique (Fig. 14, Fig. 15) and building a connected body of evidence incrementally (Fig. 20).

### An integral theory perspective

Integral theory unites objective, subjective, individual and collective dimensions into a more complete, complementary approach (Brown 2007). It highlights the systemic, cultural, behavioural and psychological aspects of sustainability (Brown 2006). Each is important for achieving SDGs and well-integrated initiatives must synthesise them all. However, many disciplines or sectors focus strongly on one or two of these aspects at the expense of the others. Neglecting one of these components creates a point

of potential failure. For example, a sustainability initiative which does not account for cultural norms may face strong objections from the community.

MetaMAP integrates these four integral aspects. Concept maps can be made up of subjective and objective components. The framework includes both 'soft' aspects of society such as cultural values and wellbeing, and 'hard' attributes like population demographics (Fig. 3). By notating concept maps, MetaMAP allows users to reflect subjectively on objective issues, such as how they feel about an existing policy or technology. Users can also objectively confirm or negate a subjective insight by attaching evidence (Fig. 20) and providing critique (Fig. 14). Another way in which Integral theory is incorporated into MetaMAP is the ability to put oneself in the system—a first person perspective into a systemic analysis (Fig. 18). The 'guiding principles' component of MetaMAP helps shared values to guide the design of interventions (Fig. 6). Like other parts, these values are open to critique and development. In these ways, MetaMAP helps users to connect objective, subjective, individual, and collective dimensions of sustainability issues in practice.

### Limits of the MetaMAP framework and further development

MetaMAP has many unique features, but it represents one method among many for understanding related issues and informing SDG outcomes (see *Introduction and Background*). MetaMAP's categories and emergent properties help to organise content and prompt users to expand their scope of concern. However, it may be easy to overlook issues not represented in the framework. Further, the scales provided are limited and not suitable for all situations. MetaMAP's realms, categories, and scales are convenient heuristics to guide perception and organise concept maps. While the framework does represent and reinforce a particular worldview, it is not intended to precisely describe reality. It is important to take a 'loose fit' approach when using MetaMAP so that it expands and not restricts the issues being considered. An iterative approach also helps users to make a first attempt at locating an important concept and then adjust it if necessary, usually after negotiating with collaborators. The MetaMAP framework can also be tailored to suit specific applications, as has been proposed for planetary health and agriculture.

At first glance, it may appear that the complexity of MetaMAP may restrict its audience. However, the analogue tool is relatively simple compared with many common tools and programs used by a wide spectrum of the population. Many professional software (e.g., GIS, architectural design), visual design (e.g., Photoshop, InDesign), social media (e.g., Facebook), and educational platforms and strategy games

(e.g., Civilisation) are far more complex. Common programs designed for untrained users like Google Sketchup have more functions and tools than MetaMAP. Even the language of lines and icons used to direct traffic on roads is more complex. The design of MetaMAP employs many visual methods to make it intuitive to use: The ‘Landscape of ideas’ makes the positions of concepts spatial rather than abstract; scale is aligned with foreground/background to mirror our vision; arrows and icons are increasingly familiar to more of the population; and the first-person perspective resembles computer games and the dashboard of a car. Each improvement in MetaMAP’s intuitiveness greatly increases the potential user base. Despite these strategies for increasing usability, MetaMAP is better suited for use by those deliberately engaging in sustainability rather than to encourage engagement by disinterested or unfamiliar parties.

The outcomes of using MetaMAP depend on the perspectives and experiences of users, group dynamics, and the various purposes of the exploration. This is true of all qualitative modelling where the agile boundaries are both valuable (in that they support holism, self-reflection, and challenging the status quo), but also challenging (where critical issues are neglected or unsupported by evidence). Users are encouraged to pay close attention to the diversity of their team, and seek critique and input from perspectives which may be underrepresented.

It is also important to note that the investigators/strategist using MetaMAP may not necessarily be the primary actors (e.g., in the case of a consultant team working on behalf of a client). This is a perfectly legitimate use of MetaMAP. In addition, one of the purposes of MetaMAP is to shift the user’s perspective of themselves from that of an outside observer to an active agent. For example, a scientist observing a system still acts on the world via their communication and other influences. MetaMAP helps to highlight these opportunities for action. Different actor groups (e.g., scientists, policy makers) can use different ‘layers’ on the user dashboard to represent their discrete, but complementary actions on a system. It is up to the judgment of users to determine which perspective is most useful for which purpose.

Some users are understandably uncertain about where to locate some concepts, or how to represent particular relationships on the map. Sensemaking and design tools like MetaMAP need to be flexible to facilitate ease of use and rapid prototyping of ideas. Being overly concerned with how to represent one issue, may undermine users’ comprehension of the whole system and potential strategic opportunities to make change. This can be further developed into quantitative models for detailed analysis of factors which can be easily quantified. However, we urge caution that important factors which are difficult to

quantify (e.g., social values or emergent properties) are not neglected in decision-making.

Several insightful users and reviewers have proposed additional factors which could be included in MetaMAP. These are received gratefully, and further developments are underway. However, there is a lot of competition for different parts of the graphic language (e.g., colour coding, position, symbols) and MetaMAP must help users to manage complexity so that they may have insight into how a system works and where to act. The functionality of the proposed digital interface could help to expand the factors included while managing visual complexity (e.g., by switching between views).

Applying MetaMAP to a broader range of case studies will support its development and tailoring to different uses and stakeholders. Many such case studies have been developed (Table 1) and a systematic review of these studies is under way. However, case studies to date are heavily weighted toward urban development in Australia, so further diversity of other sectors, scales, and national contexts is needed. Finally, there is a need for a comparative analysis among MetaMAP, existing tools, and emerging tools to support mutual learning. This is being developed in an upcoming publication.

## Conclusion

This paper introduced MetaMAP as a graphical tool to help understand and design interventions to achieve SDGs collaboratively. MetaMAP can help to address several critical challenges for sustainability related to more holistic thinking, improved communication of complex issues, and facilitated collaboration across disciplines and other social barriers. MetaMAP has been applied to diverse sustainability challenges, demonstrating its suitability to a broad range of application domains and user groups (Table 1). MetaMAP’s six core components (Landscape of Ideas, Concepts, Links, Insight, Self and Guided processes) help users to discuss and gain insight into a wide range of sustainability issues. This application was demonstrated by a small-scale case study where an interdisciplinary team conducted a case study of an Ecovillage and developed strategies to contribute to multiple SDGs synergistically. Examining MetaMAP from four different disciplinary perspectives highlighted important theory and how MetaMAP helps users to apply it in practice.

MetaMAP is designed to help researchers, policy makers, and practitioners to understand sustainability challenges more holistically, integrate diverse perspectives and design more synergetic interventions. More broadly, these types of integrated frameworks and tools will become critical for guiding interdisciplinary collaboration as we transform society to live our ambitions for a sustainable future.



**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s11625-022-01157-4>.

**Funding** Open Access funding enabled and organized by CAUL and its Member Institutions.

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