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A Knowledge Brokering Framework for Integrated Landscape Management

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Sustainable land management is at the heart of some of the most intractable challenges facing humanity in the 21st century. It is critical for tackling biodiversity loss, land degradation, climate change and the decline of ecosystem services. It underpins food production, livelihoods, dietary health, social equity, climate change adaptation, and many other outcomes. However, interdependencies, trade-offs, time lags, and non-linear responses make it difficult to predict the combined effects of land management decisions. Policy decisions also have to be made in the context of conflicting interests, values and power dynamics of those living on the land and those affected by the consequences of land use decisions. This makes designing and coordinating effective land management policies and programmes highly challenging. The difficulty is exacerbated by the scarcity of reliable data on the impacts of land management on the environment and livelihoods. This poses a challenge for policymakers and practitioners in governments, development banks, non-governmental organisations, and other institutions. It also sets demands for researchers, who are under ever increasing pressure from funders to demonstrate uptake and impact of their work. Relatively few research methods exist that can address such questions in a holistic way. Decision makers and researchers need to work together to help untangle, contextualise and interpret fragmented evidence through systems approaches to make decisions in spite of uncertainty. Individuals and institutions acting as knowledge brokers can support these interactions by facilitating the co-creation and use of scientific and other knowledge. Given the patchy nature of data and evidence, particularly in developing countries, it is important to draw on the full range of available models, tools and evidence. In this paper we review the use of evidence to inform multiple-objective integrated landscape management policies and programmes, focusing on how to simultaneously achieve different sustainable development objectives in diverse landscapes. We set out key success factors for evidence-based decision-making, which are summarised into 10 key principles for integrated landscape management knowledge brokering in integrated landscape management and 12 key skills for knowledge brokers. We finally propose a decision-support framework to organise evidence that can be used to tackle different types of land management policy decision.

Keywords: integrated landscape management, multi-functional landscapes, sustainable agricultural intensification, natural resource management, decision support, knowledge broker, science-policy interface, science into policy

INTRODUCTION

Integrated Landscape Management

Around the world land, water, and ecosystems face greater pressure than ever before. The expansion and intensification of agriculture to feed the demands of a growing and increasingly wealthy global population has had profound effects on the functioning of natural ecosystems (Foley et al., 2005). Agriculture currently occupies almost 40% of the global land surface (World Bank, 2019). While that figure has remained relatively static since the early 1990s, the management of farmland has been intensifying around the world. For example, there was a 700% increase in global fertiliser use and a 70% increase in land under irrigation in the second half of the twentieth century (Matson et al., 1997; Tilman et al., 2001; Foley et al., 2005). Green revolution agricultural intensification has led to the homogenisation and simplification of farmed landscapes, increasing production to the detriment of other ecosystem services. If current trends in food consumption and waste continue, global food production will have to increase by around 70% by 2050, driving further intensification (Alexandratos and Bruinsma, 2012). Agriculture already contributes to large-scale water pollution (from nutrients, pesticides, pathogens and sediment), soil degradation (e.g., through erosion, loss of organic matter, and salinization), over-exploitation of water resources, and air pollution. It is responsible for around 24% of global anthropogenic greenhouse gas emissions (Smith et al., 2014). Agriculture and land conversion for agriculture are the biggest drivers of deforestation, environmental degradation and biodiversity decline at a global scale (FAO, 2016; Maxwell et al., 2016; Springmann et al., 2018; WWF, 2018; Sánchez-Bayo and Wyckhuys, 2019; Willett et al., 2019).

The challenge facing decision makers in community groups (e.g., farmers' cooperatives), local and national governments, non-governmental organisations (NGOs), development banks, and agricultural development programmes is stark. They need to tackle the environmental, social, and economic problems caused by unsustainable land management, whilst at the same time ensuring that farming provides economic sustainability, healthy diets, human well-being and social equity (Smith et al., 2017). A key part of the problem is that the interests of farmers and wider communities are often misaligned. While land management decision making takes place at the farm-scale, many of the cumulative impacts of these decisions are felt across landscape, national or global scales. Policymakers operating at these larger scales need to work with farmers to find solutions that deal with broad environmental, social and economic problems caused by unsustainable land management whilst addressing local farmer and community priorities. Their policies and programmes also need to consider global trends, e.g., in climate change, commodity prices, pests, diseases, migration and urbanisation, which in turn influence local outcomes (Hecht, 2010; Liu et al., 2013). Policies and programmes should be sensitive to local customs, social values and norms so that farmers are empowered to implement practices that are appropriate to local conditions. Such policies should also take account of potential interactions and unintended consequences. The environmental benefits or impacts of many of these interventions may be impossible to measure or attribute, and take decades to manifest.

In short, landscapes need to be managed for multi-functionality in terms of ecosystem functions, ecosystem services, and human well-being across multiple scales (OECD, 2001; DeClerck et al., 2016; Manning et al., 2018; Jones et al., 2019). Sustainable multifunctional landscapes are created and managed to simultaneously provide food security, livelihood opportunities, maintenance of species and ecological functions, and fulfil cultural, aesthetic and recreational needs (O'Farrell and Anderson, 2010). The need for such multifunctionality is increasingly recognized in order to halt and reverse declining trends in ecosystem service provision (OECD, 2001; O'Farrell and Anderson, 2010; DeClerck et al., 2016; Manning et al., 2018; Jones et al., 2019). Furthermore there is increased need for landscapes that assist species in responding to increasing climate pressures, facilitating movement and allowing them to establish populations in new emerging ecosystems (O'Farrell and Anderson, 2010; DeClerck et al., 2016).

The solutions to such complex land management challenges are unlikely to lie solely in new technologies. What is needed are systemic approaches; applying existing interventions in a more integrated, synchronised and targeted way (Jagustović et al., 2019). Principles and tools are emerging to help with this (Sayer et al., 2013).

A wide range of different terms have been used to refer to the integrated management of landscapes for multiple simultaneous objectives (Reed et al., 2016). *Natural resource management* is widely used to refer to the environmental and economic management of land, water and related resources (Denier et al., 2015). This includes the conservation of ecosystems, agriculture and broader land-use planning. So called *landscape approaches* to natural resource management often aim to address multiple environmental and livelihood considerations at large spatial scales, linking policy and practice, and taking human activities and institutions as integral parts of the system (FAO, 2012; Scherr et al., 2012; Milder et al., 2014; Sayer et al., 2017). Such approaches frequently incorporate multi-stakeholder processes to help coordinate land management to achieve environmental, social and economic outcomes simultaneously (Minang et al., 2015), and to reconcile the needs of people within the landscape with those outside, such as national governments (Denier et al., 2015). They often bring together policy and practice for competing land uses through adaptive management systems (Reed et al., 2014a). The term *sustainable land management* can refer to activities from farm to landscape-scale but is often used to refer to activities that focus on site level actions and particular stakeholder groups (Denier et al., 2015).

In this paper we use the term *Integrated landscape management* to refer to landscape-scale policy, planning or management initiatives that aim to simultaneously improve food production, environmental outcomes, rural livelihoods and governance (Estrada-Carmona et al., 2014; Milder et al., 2014). For the purposes of this paper, a landscape is defined as a geographically distinct area of land that is bigger than a single farm. This can be defined politically (e.g., district), hydrologically (e.g., river basin), agriculturally (e.g., agroclimatic zone), economically (by market), culturally (e.g., Globally Important Agricultural Heritage Sites), or ecologically (e.g., by ecosystem or by designated protected areas such as national parks). However the boundary is defined, we consider landscapes as socio-ecological systems in which social, cultural and economic elements interplay with ecological and biophysical ones (Sayer et al., 2013).

Although many traditional farming systems were built around multi-functionality, mainstream agricultural development and environmental conservation programmes and policies have tended to focus on single issues. Multi-objective integrated landscape management programmes, however, have been around for some time and are becoming more prevalent (Denier et al., 2015). For example, recent assessments of community-based natural resource management initiatives identified 428 integrated landscape initiatives that have been established to improve agriculture, livelihoods, and the environment in Africa (Milder et al., 2014), Latin America and the Caribbean (Estrada-Carmona et al., 2014), South and Southeast Asia (Zanzanaini et al., 2017), and Europe (García-Martín et al., 2016). Several of these initiatives are associated with specific integrated landscape management mechanisms, including biosphere reserves, model forests, biological corridors, integrated catchment management, and forest restoration for climate change mitigation (e.g., REDD+).

Evidence Into Policy

Many authors have argued that robust science is essential to inform effective integrated landscape management (Cash et al., 2003b; Collier et al., 2011; Gusmão Caiado et al., 2018). It can support decision making by quantifying uncertainty around interventions, highlighting previously unforeseen issues, reducing personal bias and increasing trust in a policy from the perspective of policymakers, lobby groups and the public. Science can also help to understand the consequences of different moral and ethical choices (Lubchenco, 1998). Science plays different roles for different types of decision makers. At an international level, it can facilitate dialogue and help set narratives, providing common ground between international players. Within national government ministries it informs the design and implementation of government policy. At the local level it can provide stakeholders with much needed practical evidence of what works.

A major barrier to the design of effective land management and conservation programmes is the limited accessibility and fragmentation of scientific evidence (Sunderland et al., 2009). Experimental research is by necessity reductionist, often focusing on one problem or intervention at a time, and ignoring the complex interactions between them. This can be difficult to reconcile with the broad, holistic framing of policy questions (Pullin et al., 2009). On top of this, evidence on the effectiveness of land management interventions is often site-specific and difficult to transfer from one location to another. Monitoring the impact of integrated landscape management programmes is technically difficult due to funding constraints, time lags and confounding effects between interventions (Estrada-Carmona et al., 2014; Milder et al., 2014; García-Martín et al., 2016; Zanzanaini et al., 2017). Despite rhetoric of integration, there is evidence that many researchers working in conservation and development are still firmly rooted in their disciplinary silos (Reed et al., 2016). Decision makers are unfortunately often left to themselves to piece together a systemic understanding of their specific situations.

This gap between science and policy is well-recognised and various authors have proposed ways to bridge it (Lubchenco, 1998; Wilson et al., 2007; Godfrey et al., 2010). Many involve collaboration between policymakers and evidence providers throughout the process of scoping, procuring, interpreting and synthesising applied research (Wilson et al., 2007; Godfrey et al., 2010). The challenges set out above, however, mean that traditional scientific approaches cannot alone provide all the answers. Instead, evidence used in policymaking needs to encompass judgments, opinions, beliefs, and analysis (Wilson et al., 2007). This broader view is often provided through professional consultancy (Funtowicz and Ravetz, 1994).

The high levels of uncertainty and high decision stakes inherent in many environmental issues mean that policy decisions need to be based on values as much as "facts." Post-normal or transdisciplinary processes involve the stakeholders affected by the issues in dialogue with scientific experts and decision makers to explore solutions (Funtowicz and Ravetz, 1994). These approaches place formal scientific information alongside the diverse values, opinions and local tacit knowledge of actors who are affected by the issues (Funtowicz and Ravetz, 1994; Wilson et al., 2007). They bring together evidence from different natural and social science disciplines alongside lay knowledge, local priorities and values (Tress et al., 2005). Furthermore, they imply a broader role for science and new ways of working to lead and inform public dialogue in addition to informing policy (Lubchenco, 1998; Giller et al., 2007; Rietig, 2016).

Knowledge Brokering

In this paper, we use the term *Knowledge Brokering* to describe the full range of activities that bring together policymakers and researchers to develop a systems understanding of a given situation, and to develop evidence-informed policy. Knowledge brokering is a two-way participatory process in which researchers come together with policymakers, agriculture professionals and other stakeholders to share perspectives and learn from each other (Pretty, 1995). It covers a repertoire of activities including supplying knowledge (linking policymakers to experts), bridging (mediating and translating between science and policy), and facilitating interaction and collaboration between researchers and policymakers to co-produce knowledge (Turnhout et al., 2013). Knowledge brokers can include applied researchers, technical policy advisers (e.g., in government departments or NGOs, or the staff of third party institutions (e.g., think tanks or consultancies). In some cases, specific institutional structures either in research or policy organisations can fulfil this function (Godfrey et al., 2010).

Knowledge brokers can play an important role in bringing together strands of evidence to form a more holistic view of problems. They can support decision makers in accessing, interpreting and contextualising evidence, and support researchers to understand the policy context in which evidence is used. This requires skills in evidence synthesis and transdisciplinary approaches alongside non-scientific, translational skills (e.g., negotiation and group facilitation) to help break down boundaries between disciplines and professions (Schwartz et al., 2017). Knowledge brokers can help bridge between the world views of different interest groups, facilitating and supporting public and political dialogue (Giller et al., 2007).

As well as providing clear benefits for policymakers, knowledge brokering provides a mechanism to improve the impact and uptake of research. This is increasingly demanded by funders wanting to ensure value for money from their research investments, research organisations wanting to demonstrate impact and researchers themselves who are motivated to invoke positive changes as a result of their work. Identifying the appropriate tools to inform specific decisions in the management of complex socio-ecological systems poses a significant research challenge in its own right (Bennett et al., 2015). Many efforts to communicate knowledge to policymakers in the past have involved a unidirectional push of information through knowledge transfer or "scaling" initiatives (Godfrey et al., 2010). These have often been based on linear *theories of change* or *impact pathways.* This type of supply-driven approach has its limits. The common understanding of change as a linear process does not capture the complexity that is inherent in most development problems (Young et al., 2014). Co-designed solutions are more likely to have buy-in and a higher probability of self-sustained uptake. Supply-driven approaches to knowledge transfer often aim to influence decisions based on the findings of individual research projects. In contrast, demand-driven knowledge brokering approaches often draw on the weight of evidence built up on a given topic over multiple years. In such cases, knowledge brokers work with decision-makers and guide them through the evidence-base to support the design of effective interventions (Luedeling and Shepherd, 2016).

Aims

This paper is aimed at individuals and institutions working at the science-policy interface on integrated landscape management who act as knowledge brokers. It reviews evidence on what works to inform policy decision making to achieve multi-functional landscapes that deliver local, national and global sustainable development objectives. Our review is particularly focused on landscape-scale, multi-objective programmes and policies. We explore how to combine different types of evidence to inform the development of policies based on a systemic understanding of inherent complexity. This includes approaches to facilitate collaboration between researchers and decision makers, existing frameworks to organise evidence, and decision support approaches. From this, we set out guidelines for integrated landscape management knowledge brokering in integrated landscape management. We also propose a general decision support framework based on a typology of policy decisions that can be used to guide knowledge brokers and decision makers in how to answer complex questions that require the integration of multiple evidence strands.

DECISION MAKING IN INTEGRATED LANDSCAPE MANAGEMENT

Actors and Their Decisions

One of the challenges of integrated landscape management is that control is spread over a wide range of actors. The way that land is used and managed is influenced by the interplay of policies and initiatives from local and national governments, non-governmental organisations, community initiatives, private companies, as well as a wide range of other external factors. Successful integrated landscape management requires coordination between stakeholders at all these levels. This can occur through participatory approaches or social learning frameworks (Estrada-Carmona et al., 2014; Milder et al., 2014).

This paper focuses on actors who are implementing multi-objective landscape-scale policies and programmes, including:

- **Landscape-scale decision-makers** (Local government; NGOs; community groups; local farmer groups; Integrated Landscape Management initiatives; private companies).
- **National-scale decision-makers** (Government ministries; NGOs; development banks; agricultural development programmes; industry groups such as farmers' unions).
- **International-scale decision-makers** (UN Organisations; intergovernmental panels; regional organisations such as the African Union; overseas development assistance programmes; private multinational companies).

Although actors in the groups listed above are often those with the power, resources and legitimacy to initiate integrated landscape management approaches and policies, there are many other stakeholders that influence or are influenced by their decisions. These groups need to be engaged through participatory approaches and governance structures. This is not without its challenges. Integrated landscape management programmes frequently cite barriers including difficulties in maintaining infrastructure and institutions, difficulties in engaging stakeholders (particularly from government and the private sector), coordination difficulties in moving from a sectoral to an integrated approach, entrenched power dynamics, and unsupportive policy frameworks. The resources, capacity and influence to work effectively at landscape-scale can preclude small organisations from taking part. Maintaining stakeholder engagement is frequently hampered by funding constraints and time lags in achieving results (Estrada-Carmona et al., 2014; Milder et al., 2014; García-Martín et al., 2016; Zanzanaini et al., 2017).

We use the term "policy" in a broad sense to cover laws, policies, programmes, investments, and other coordinated interventions to deliver integrated landscape management. Policymaking is frequently presented as a cyclical process through which decision makers iteratively prioritise, plan, implement, monitor, and evaluate. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), for example, considers a policy cycle of (i) agenda setting; (ii) policy design; (iii) policy implementation; and (iv) policy review (IPBES, 2016). They use this to categorise the potential uses of ecosystem service tools.

In practice, policymaking rarely happens in such a structured way. Instead, it tends to be opportunistic with steps occurring simultaneously or out of sequence. Processes can be complex and non-linear (Ademokun et al., 2016). However, even if the concept of a policy cycle is idealised in terms of sequence and process, it provides a good way of categorising the types of decisions that need to be made during the planning of a multi-objective, landscape-scale policy or programme. Viewed thus, the steps of a policy cycle can provide a typology of decisions faced by the actors described above. Various authors have proposed integrated landscape management decision support frameworks structured around a policy cycle (e.g., McGonigle et al., 2012; Young et al., 2014; Girvetz et al., 2017).

Knowledge brokers can play an important role in facilitating links between policymakers, scientists and wider actors for various types of land management decisions. We have broken down the relevant challenges facing policymakers into seven parts (**Figure 1**). These are grouped into the four components proposed by Girvetz et al. (2017). Although presented as a cyclical set of decision steps, the parts and components can stand alone.

Component 1: Situation analysis. A first step in policy or programme design is one of prioritisation. This process may feed into the development of a business case or funding proposal. At this stage, the role of knowledge brokers is to bring together stakeholders to map systems, understand problems, explore conflicting interests, and envision futures. It includes ***1a. Stakeholder engagement***, identifying key actors and developing plans to involve them in problem framing, and ***1b. Prioritisation***, which can involve participatory approaches to identify issues, establish baseline information, map system relationships, understand conflicting interests, and envision futures.

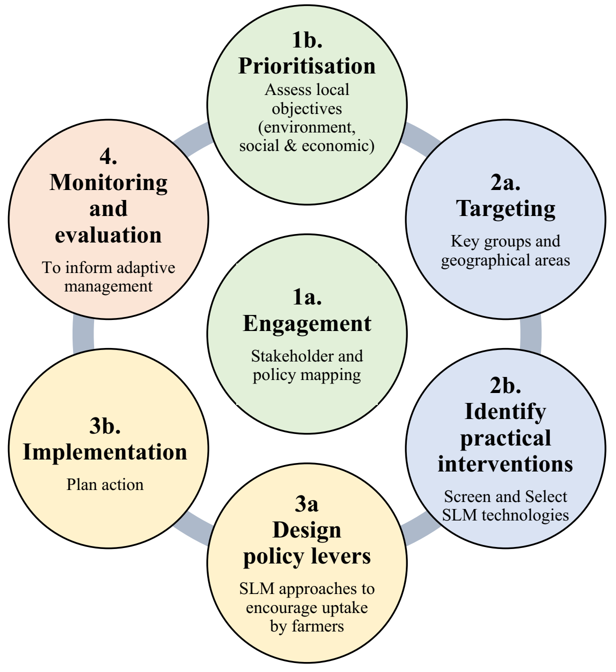

FIGURE 1 | Idealised policy/programme design cycle for integrated landscape management. This provides a typology of decisions and design phases. Decision approaches and toolkits to support each of the seven stages are sketched out in **Table 3**.

Component 2: Prioritising interventions focuses on what to do and where to do it through ***2a. Targeting*** and ***2b. Identifying interventions***. Knowledge brokers have a role here in linking with academia and joining up many fragmented studies on individual interventions to develop a holistic picture of what works where. Integrated landscape management can involve a wide range of potential technologies or interventions implemented systematically (WOCAT, 2019). These include:

- **Farm management practices** (e.g., integrated pest management practices, tillage practices, fertiliser management, irrigation practices).
- **Land restoration interventions** (e.g., radical terracing, bunds, crop targeting, agro-forestry, livestock exclusions).
- **Forest management and restoration practices** (e.g., natural regeneration, tree planting, harvesting timber and non-timber forest products).
- **Farm system changes** (e.g., switching from conventional to organic farming, integrated farm management, or holistic agroecological approaches).
- **Land-use changes** (e.g., crop changes, reverting from arable to grassland, agriculture to forest, or other uses).

The solution most appropriate to one landscape is not necessarily transferable to another. Targeting is therefore essential to ensure that the right interventions are taken up in the right place. This is not as simple as it seems, however, since most of the landscape, national or international scale decision-makers described above do not have direct control over resource use

TABLE 1 | Categories of levers and policy interventions to encourage changes in land use and management.

Category	Examples
Knowledge	**Knowledge generation:** research and development new technology and practices. **Knowledge dissemination:** information campaigns; training; extension; demonstration; networks; farmer groups.
Access to materials	**Enhancement of seed systems**. **Supporting access to equipment and other inputs:** germplasm, fertiliser, water, etc.
Financial	**Markets and finance:** value chain interventions; micro-finance; market access; cooperatives; opportunities for women/youth; product innovation; consumer awareness campaigns. **Financial incentives:** product differentiation (certification/ labelling); payment for ecosystem services.
Legal and institutional	**Legal and social:** Institutional capacity development; land tenure.

and management (including for example land, water, energy, and human resources). They need to apply policy levers [or *Sustainable land management (SLM) approaches* c.f. (WOCAT, 2019)] to encourage land management change. Maps, datasets and evidence to inform targeting often need to be compiled from many sources.

Component 3: Programme design and implementation. ***3a. Programme design*** needs to be based on an understanding of local barriers, which can include education, access to extension, land tenure, access to credit, labour availability, access to tools, social networks and environmental factors (Teklewold et al., 2012; Kassie et al., 2013; Haile et al., 2017; Mutyasira et al., 2018). Potential levers therefore include supporting land managers with knowledge, access to materials, financial incentives or changes to legal and institutional settings (**Table 1**). ***3b. Implementation*** needs to take account of the practical and economic barriers to policy levers. Knowledge brokers need to source evidence for programme design from social researchers, economists and other experts, while engaging those responsible for on-the-ground delivery to make sure that approaches are practical, locally relevant and likely to be effective.

Component 4: Monitoring and evaluation. Finally, robust plans are needed for monitoring the social, economic and environmental impact of interventions. This is fundamental for identifying adjustments that are needed to secure sustainable development outcomes and to reduce or remove undesirable consequences (Selomane et al., 2015). Monitoring and evaluation increases the transparency of investments and helps institutions using public funds to be held accountable for expenditure (Piirainen, 2014). It also supports learning through an adaptive management process and should therefore be a core part of intervention planning.

Windows of Opportunity for Change

Researchers and knowledge brokers need to be aware of the wide range of political, economic, social, and environmental factors that limit the scope of actors to influence change. Governments, for example, are constrained by the need to ensure that policies are affordable, implementable and popularly acceptable, that laws are enforceable, and that appropriate institutions are in place to roll out large-scale programmes.

A window of opportunity for policy can be said to exist when action is politically desirable, when there is public perception of the problem and a desire to address it, and when cost-effective interventions exist (Kingdon, 1995, in Rucklehaus 2015).

In practical terms, national scale policies and laws often remain static for years, amended during short periods of intense activity. For example, in the period before elections, manifestos are developed which can set the policy direction over the term of a government. New governments may launch consultations, white papers or plans setting the trajectory for policy over longer timeframes. Other laws, directives, international agreements and targets may be reviewed periodically, for example every 5–6 years in the case of European Directives. International initiatives such as the UN Sustainable Development Goals set the agenda for years once agreed. These periods of review or negotiation can provide opportunities for tailored science-policy dialogue, for example exploring evidence on the effectiveness of potential new policy interventions (McGonigle et al., 2012). Such windows of opportunity are often predictable but can be hard to anticipate from the outside (Rose et al., 2017).

Opportunities for landscape management change can also arise from often unfortunate driver events, such as natural disasters, floods, serious land degradation, socioeconomic crashes, or political events that create pressure for change (Rose et al., 2017). Political factors can affect the response to such shocks. For example, donors were slow to act in response to the Ethiopian food crisis in 2000, because they hoped to use aid as leverage to quell an ongoing armed conflict in the region (Broad and Agrawala, 2000). Upon the food crises Ethiopia has drastically strengthened their National Social Safety Net programme and their Sustainable Land Management programme, which are now globally renowned and have buffered several new food crises (Berhane et al., 2013).

Researchers and knowledge brokers need to develop an awareness of these windows through regular and ongoing dialogue with policymakers. They need to predict them, respond to them rapidly as they occur, use them to frame research and knowledge products appropriately, and persevere with engagement between windows (McGonigle et al., 2012; Rose et al., 2017; Pali et al., 2018). Where possible, researchers need to work with policy makers and civil society organisations to create windows of opportunity through agenda-setting, coalition building, and policy learning (Ashford et al., 2006).

INTEGRATING DIFFERENT TYPES AND SOURCES OF EVIDENCE

Types and Quality of Evidence

Evidence for integrated landscape management comes in many forms. It includes, for example, scientific evidence, anecdotal evidence, and evidence based on professional experience. Several authors have proposed ways to categorise evidence. These vary in relation to the field considered (Anon, 2014; Ademokun et al., 2016). Categories include:

- **Data and statistics** (quantitative and qualitative),
- **Research evidence** (experimental evidence including participatory research and citizen science),
- **Process theory** (systems maps, evidence-informed models, theories of change, or impact pathways),
- **Observational evidence** (practice informed or implementation evidence), and
- **Local or indigenous knowledge** (can include experiential, traditional, or lay knowledge about local conditions, effects, or practices).

Some types and sources of evidence carry more weight than others. For example, a survey of decision makers in the health sector found that systematic reviews are a particularly well-favoured source of evidence, followed closely by quantitative research. Evidence strength and consistency, data quality, bias and publication date were all cited as key factors affecting the influence of a study on policy (O'Donoughue Jenkins et al., 2016).

The weight attached to research evidence depends to a great extent on the design of studies. In the health sector, for example, Randomized Controlled Trials usually carry more weight than less rigorous experimental and quasi experimental designs, which in turn carry more weight than expert opinion (Hansen, 2014). DFID has set out guidance to assess the quality of individual studies and wider bodies of evidence based on their design, relevance and consistency (DFID, 2014).

While such hierarchies of evidence are useful to help interpret the weight of evidence on a particular intervention, integrated landscape management carries its own specific evidence challenges. Evidence is often highly fragmented, only covering certain parts of the system in question. Knowledge brokers and policymakers often need to contextualise evidence, rapidly filling gaps. In practice, this means building on all sources of information available, while taking account of the relative weighting of different information sources.

Large-scale field research on integrated landscape management carries further difficulties. The number of factors affecting environmental and social variables and the heterogeneity of landscapes make replication and control almost impossible. Time lags between intervention and effect, unpredictable interactions between factors and tipping points all add further challenges. Furthermore, many of the practices associated with integrated landscape management are highly site-specific and yet have cumulative off-site impacts. Many agroecological practices rely on farmers implementing combinations of practices based on a systems understanding. These are difficult to implement, and it is difficult to demonstrate impact.

Assessing the effectiveness of knowledge-based interventions (see **Table 1**) is particularly difficult when the expectation is for farmers to adopt complex management practices. A recent systematic review, for example, found relatively few high-quality studies demonstrating evidence of the effectiveness of farmer training to boost farmers' income and household food security. Simpler input innovations on the other hand, such as introducing new crop varieties, fertilisers or plant protection products, have been frequently shown to be effective at boosting household food security and nutrition (Stewart et al., 2015).

While longitudinal studies and Before-After-Control-Impact (Smith, 2002) designs may help to address some questions on the effectiveness of interventions at scale, researchers and policymakers are obliged to piece together knowledge from multiple sources, projecting large-scale and long-term effects using models and decision support tools, based on many assumptions. Complex land management policy decisions therefore almost always have to be made on incomplete or patchy evidence drawing on the full range of information available including data, research evidence, process theory, observational evidence, expert opinion, and local knowledge. Evidence needs to be consolidated, combining formal synthesis and systematic reviews (e.g., Sargeant et al., 2006), with modelling and expert elicitation, building on the best information available (Morgan, 2014). Developing this type of evidence narrative is a specialism in its own right, and a key role for integrated landscape management knowledge brokers.

Local or indigenous knowledge can be invaluable in informing integrated landscape management policymaking and can be used in combination with scientific evidence (Rathwell et al., 2015; Alexander et al., 2019). The value of such knowledge has been gaining increasing recognition, particularly among the conservation community where conservation organisations are increasingly asked by donors to take community-based approaches that consider indigenous knowledge. The knowledge and values of stakeholders are also vital in transdisciplinary or post-normal approaches that incorporate stakeholder engagement into the process of developing evidence (Funtowicz and Ravetz, 1994).

Examples from the literature show how evidence across all these types can potentially be misused, unintentionally or intentionally. Actors may preferentially "cherry pick" evidence that supports their own viewpoint (Rietig, 2016). Private sector interest groups can influence the use of evidence in policies and programmes (Waqa et al., 2017). Political lobbyists may use evidence to push a particular agenda (IOB, 2015). This is a particular problem in integrated landscape management where groups have conflicting interests and may present skewed evidence that supports their positions. The ability to access and use evidence to support a particular decision may also be unevenly distributed across interest groups leading to potential bias, creating a challenge for knowledge brokers.

While policymakers and lobbyists sometimes pick evidence to support their position, researchers themselves are not immune from bias. The personal values of scientists can, e.g., influence the way in which they frame research questions and portray results (Pretty, 1995). Bias can also come from a misunderstanding of the conclusions that can be drawn from a result, or extrapolation of results into different contexts beyond reasonable limits. "Expert" stakeholders are often overconfident in their own knowledge (Morgan, 2014). Techniques like calibration training can help stakeholders to better judge the limits of their knowledge

(Whitney et al., 2018a,b). These potential sources of bias make the role of knowledge brokers especially important as neutral, honest brokers (Cvitanovic et al., 2016). However, knowledge brokering can never be fully neutral; selecting, which knowledge to share is inherently laden with values (Shaxson et al., 2012).

Barriers to the Use of Evidence

There are many potential ways in which decision makers can access evidence. They can get information directly from scientific literature, data interrogation, or internet searches; from evidence syntheses and policy briefs (e.g., Conservation Evidence, 2019; Sutherland et al., 2019); or indirectly from expert advisers, consultants, national research centres, lobby groups, and Non-Governmental Organisations.

Many decision makers value the supporting role of scientific evidence. A 2013 survey by the UK Department for International Development (DFID), for example, found that 87% of staff felt using evidence was important for their work (DFID, 2013). However, policymakers and practitioners relatively rarely access primary scientific literature (Sutherland et al., 2004; Sunderland et al., 2009). This can be due to a lack of scientific literacy, lack of access or because studies lack the interdisciplinarity to tackle the complexity of real-world policy problems (Sunderland et al., 2009; Oliver et al., 2014; Rose et al., 2017). Often decision makers simply lack time to analyse scientific literature, which is often written for academic dialogue rather than for informing policy. Secondary sources can be much more important for time-pressed policymakers. Experts consulted by policymakers thus play an important role as advisers or professional consultants (Funtowicz and Ravetz, 1994). The effectiveness of the relationships of such advisers with policymakers is enhanced over time as they build mutual trust (Lubell, 2007; Masset et al., 2011).

The use of evidence in policymaking seems rarely to be limited by a lack of available information. Rather, conflicting values, interests and world views are key limiting factors (Rose et al., 2017). Policymakers faced with a plethora of inconsistent and conflicting recommendations, tools and resources often rely on experiential knowledge rather than scientific evidence (Cvitanovic and Hobday, 2018). This has led to calls of "evidence complacency" from some in the research community (Sutherland and Wordley, 2017).

There are many reasons why evidence is not taken up. Time, ease of access, costs and institutional support are cited as common constraints by policymakers in various sectors across many countries (DFID, 2013; Oliver et al., 2014; Ntshotsho et al., 2015; O'Donoughue Jenkins et al., 2016; Rose et al., 2017; Waqa et al., 2017). The relevance of research evidence is also a barrier to its use (Oliver et al., 2014; O'Donoughue Jenkins et al., 2016). Sometimes studies are not well-aligned with the actual policy options that are being proposed or do not cover a wide enough range of outcomes. Evidence is sometimes presented in a way that does not take account of policy context, windows of opportunity or of the political or economic constraints facing decision makers (Elueze, 2016). This can be because researchers do not fully understand policy questions or fail to communicate evidence in a way that is aligned to immediate policy goals (UK National Audit Office, 2003). A lack of alignment with end users' needs has been cited as a key barrier in the uptake of decision support tools and ecosystem assessments (Förster et al., 2015; Gibson et al., 2017). Organisational structures and stakeholder priorities also have a strong influence with the result that decisions are influenced by a wide range of factors other than scientific evidence (Ntshotsho et al., 2015). Social factors have also been shown to play a key role in encouraging the use of evidence. Various studies have shown that developing strong and trusted relationships with regular contact between researchers and policymakers is highly important (Oliver et al., 2014; Cvitanovic and Hobday, 2018).

The factors affecting the use of evidence in policymaking can be summarised as follows:

- *System-level factors:* communication between scientists and policymakers; political system; citizens' demand for evidence use; other stakeholders; habit; timing; changes in administration; planning; sector; quality of research and data.
- *Organisation-level factors:* organisational culture; resources; library and information services; knowledge management processes; staff turnover rate.
- *Individual-level factors:* leadership; attitudes; knowledge of how to access research; skills in evaluating evidence; skills in communicating research; IT skills; professional experience; personal judgement.

(Ademokun et al., 2016)

Policymakers, short of time and inundated with confusing and conflicting messages, may be more prone to evidence fatigue than complacency. It can be hard to know where to start to access huge volumes of scientific literature on a given topic. Serendipity is often a key factor in the use and uptake of evidence (Oliver et al., 2014).

Researchers need to do more than put findings into easily accessible formats (Rose et al., 2017). They need to make themselves accessible to policymakers. In addition, policymakers need support in accessing relevant information, and dealing with conflicting and incomplete evidence. Institutions and research funders need to consider incentive structures to encourage academics to do this. Rewards and career progression in academia are currently primarily focused on peer reviewed papers rather than on policy focused outputs (Dilling and Lemos, 2011).

BRIDGING BETWEEN EVIDENCE AND POLICY

The translation of evidence into effective policy is challenging and requires concerted effort from both decision makers and researchers to work across the boundaries of their respective communities with effective communication, translation and mediation (Cash et al., 2003b). This "boundary work" needs to ensure that scientific assessments and evidence syntheses are demand-driven, transparent, objective and technically accurate (Watson, 2005). Engaging key government, civil society and private sector actors in the generation and synthesis of evidence is key to achieving ownership and ensuring that science products are relevant, usable and accessible in the decision-making process. Above all, evidence should be presented in a way that is "policy relevant" rather than "policy prescriptive" (Watson, 2005).

Facilitating communication and collaboration between researchers and policymakers is a key role, but often one that is not formalised. In practice, this knowledge brokering role can be filled by scientifically literate policymakers, policy literate researchers, technical advisors, cabinets, or third party "boundary organisations" (including for example NGOs and consultancies) (Dilling and Lemos, 2011). Although this is an important discipline in its own right, the professional skills and career paths for knowledge brokers are not currently well-established or formalised.

Credibility, *salience,* and *legitimacy* are key factors determining the effectiveness of knowledge systems and knowledge brokers (Cash et al., 2003a; Turnhout et al., 2013). Knowledge brokers need to be able to act impartially. Mistrust between actors with conflicting agendas can create barriers to the design and adoption of policies (Yami and Van Asten, 2017). There are a number of key trade-offs that need to be considered when working at the science-policy interface. These include clarity vs. complexity (whether to focus on simple, clear messages vs. detailed and comprehensive systemic analyses); speed vs. quality (timely responses demanded by decision makers may lack robustness); push vs. pull (should the research agenda be set by policy demand or research supply?) (Sarkki et al., 2013).

TABLE 2 | Spectrum of knowledge brokering approaches. Elaborated from Michaels (2009).

Knowledge brokering types	Examples of approaches
Build capacity	**Parties work together to frame interaction as part of a joint learning process:** Co-production of knowledge; Participatory systems mapping; Decision analysis (Lanzanova et al., 2019); Sabbaticals and secondments (Gibbons et al., 2008)
Collaborate	**Parties jointly frame interaction:** Co-design of research or policies
Engage	**One party frames the discussion and involves other parties as needed:** Technical committees; Royal commissions
Match-make	**Identify what expertise is needed and make connections:** Introductions (Adelle, 2015)
Consult	**Seek expert advice:** Meetings, Interviews; One round questionnaires; Workshops; Focus groups; Delphi (Fischer et al., 2014); Research commissioning
Inform	**One-way dissemination of information:** Outreach; Evidence summaries (Elueze, 2016); Systematic reviews (Sargeant et al., 2006); Working papers; Newsletters; Social media (Newman, 2014); Blogs

The Knowledge Brokering Spectrum

A wide range of terms has been used to describe the function of facilitating access to knowledge. These include for example: Knowledge Transfer (KT), Knowledge Management (KM), Knowledge Translation (KTn), Knowledge Exchange (KE), Knowledge Brokering (KB), and Knowledge Mobilization (KMb). These can collectively be referred to as K* (KStar) (Shaxson et al., 2012). This covers a spectrum of functions ranging from linear dissemination of knowledge from producer to user, to co-production of knowledge, social learning and innovation. Over recent years, there has been a change in emphasis from uni-directional KT to multi-directional KE and KB; from *passive participation* to *functional participation* to *interactive participation* between researchers and policymakers (Pretty, 1995).

There is a large overlap between the multiple frameworks that have been proposed for classifying knowledge brokering approaches (Pretty, 1995; Michaels, 2009; Reed et al., 2014b). Michaels et al. outlined six strategies ranging from the relatively passive publication of reports and briefs (*inform*) to more collaborative approaches to work with stakeholders to *build capacity* (**Table 2**) (Michaels, 2009). This echoes literature on public participation, which discusses engagement at different levels, e.g., *communication*, *consultation* and *participation* (Rowe and Frewer, 2005). Shaxson et al. (2012) set out four types of knowledge brokering roles including: *information intermediary* (informing, compiling and aggregating information), *knowledge translator* (disseminating, translating, communicating), *knowledge broker* (matchmaking, bridging, networking, and facilitating active engagement between stakeholders), and *innovation broker* (operating at the institutional level, building capacity, negotiating, collaborating, and establishing organisational functions).

Approaches from across this spectrum of engagement all have their place. In some cases, one-way communication is needed, for example to raise awareness of a new issue uncovered by research. In other cases a more participatory, capacity building approach is required. For example, in developing an integrated landscape management programme, participation ensures that the knowledge and values of different groups are taken into account, and that decisions are co-developed through an equitable and transparent process (Sayer et al., 2013). Various initiatives have aimed to develop policymakers' capacity to use evidence. For example, the Evidence-Informed Policy Making Toolkit (developed through the DFID Building Capacity to Use Research Evidence programme—BCURE) sets out a workshop format to guide practitioners in accessing and scrutinising scientific literature (for bias, quality etc.), helping people understand experimental design, statistics and experimental limitations (Ademokun et al., 2016). There is reliable evidence for education interventions, such as critical appraisal programmes, in increasing evidence uptake (Langer et al., 2016). However, institutional changes are also necessary. Incentives are required for policymakers to use evidence, and for researchers to translate their research into practice (Turnhout et al., 2013).

In any case, there needs to be a pull for knowledge from decision makers as well as a push from researchers. Interactions between researchers and decision makers need to be demand-driven, designed into research programme plans from the outset, and based on building long-term, trusting relationships with two-way dialogue (Reed et al., 2014b). Decision makers need tangible results as early as possible in order to maintain engagement (Reed et al., 2014b).

Co-creation of Knowledge

Policymakers also need to engage to set the direction of research. Two-way communication helps to translate general "policy" questions into more specific and actionable "research" questions (Cash et al., 2003b; Sutherland et al., 2006; Cvitanovic et al., 2016). Involving policymakers in the process of research design and implementation can be an effective way of developing a shared understanding of the context for research and enhancing its communication and uptake (McGonigle et al., 2014). This can be supported by the establishment of multi-stakeholder platforms (Hermans et al., 2017) or transdisciplinary research platforms (McGonigle et al., 2014), which provide a forum for decision makers and scientists to come together. Participatory systems mapping and decision analysis approaches provide other models through which a shared understanding can be built (Lanzanova et al., 2019).

Such collaboration encourages co-development of research questions, joint design of studies and co-production of knowledge. This boosts the experiential knowledge of decision makers while making sure that research is tailored to address specific current policy questions (Cvitanovic and Hobday, 2018). Such ongoing contact allows research to adapt to a rapidly evolving policy context. Stakeholder involvement in research design and implementation also provides a forum for researchers and policymakers to interact on a more informal and *ad hoc* basis, enabling policy questions to be rapidly discussed as they arise (McGonigle et al., 2014).

Collaboration between policymakers and researchers can also provide opportunities to incorporate research principles into the design and implementation of policies and programmes in a way that builds evidence on their effectiveness. Piloting, Randomized Controlled Trials or phase-in approaches, for example, can generate evidence that can be used to self-correct or make adjustment as policy roll-out progresses (HM Treasury, 2018). This blurring of the lines between science and policy provides a new potential role for researchers in directly engaging in policy design, potentially reframing policy as a scientific endeavour (Boyd, 2019).

Co-creation of knowledge has been shown to be valuable in a number of settings. For example, the iterative co-development of aquifer models between water managers and scientists from several disciplines in Nebraska was influential on decision making at multiple levels (Cash et al., 2003a). Iteration between researchers and decision makers, involving mediation, translation and co-production, has been shown to greatly enhance the usability of evidence on climate change (Dilling and Lemos, 2011). A study assessing the impact of Regional Integrated Sciences and Assessments workgroups (climate change research/policy boundary organisations) showed that they had improved climate literacy in policymakers, enabled coproduction of knowledge, and had produced credible, salient and legitimate evidence (Franklin et al., 2018).

However, there are trade-offs in knowledge co-production. Though it increases research relevance, it can potentially impact researchers' independence and credibility. Whilst coproduction should be incentivised, it is important to appreciate that some questions may not be able to be answered in this way (Turnhout et al., 2013).

FRAMING EVIDENCE TO INFORM INTEGRATED LANDSCAPE MANAGEMENT POLICY

Although large numbers of decision support tools, case-studies and research programmes have been developed to inform integrated landscape management, there is little clear holistic guidance on the selection of appropriate approaches for given applications (Grêt-Regamey et al., 2017). This is significant because the choice of tool has a major effect on the way that problems are framed and hence the values, perspectives and assumptions built into analyses (Gasparatos and Scolobig, 2012). One way to overcome this problem is to use multiple analytical methods in combination through a "weight of evidence" approach (McGonigle et al., 2012). A combination of biophysical, economic and monitoring tools and indicators could give more nuance than a single tool. Very little work has been done to develop such multi-tool approaches, however (Gasparatos and Scolobig, 2012).

The guidance that does exist on tool selection tends to be rather general and focused on individual methods. A number of web-based tools are available to guide decision makers in selecting analytical approaches to target land management interventions. For example, the ValuES and WOCAT websites help signpost decision makers to relevant case-studies of ecosystem service evaluation in the case of the former, and sustainable land management practices in the latter (ValuES, 2019; WOCAT, 2019). WOCAT has also developed a toolkit to guide decision makers through the process of developing SLM strategies, although this does not specifically focus on evidence synthesis and contextualisation (Bastidas Fegan, 2019). The Overseas Development Institute ROMA framework provides guidance on policy engagement and influence through a flexible toolkit that combines workshops, rapid reviews, analysis and reflective learning to guide researchers and development practitioners hoping to influence policy in an iterative learning process (Young et al., 2014). The IUCN Restoration Opportunities Assessment Methodology (ROAM) is another example of a decision support toolkit targeted at forest restoration (IUCN and WRI, 2014).

To make evidence relevant to policymaking, it needs to be synthesised and packaged effectively. Dicks et al. (2014) proposed the 4-S hierarchy framework for organising scientific evidence. Scientific *Studies* are summarised by *Systematic reviews.* These feed into *Summaries* and *Decision support systems* to provide advice or guidance. However, high quality syntheses, e.g., through systematic reviews, are slow to do and may not be responsive enough for rapidly emerging policy windows (Rose et al., 2017). They also do not adequately address the inevitable gaps in evidence. There are often clear trade-offs between the confidence of an answer to a policy question and its timeliness (Sarkki et al., 2013). A rapid evidence appraisal or expert elicitation process over a few days is likely to have a more positive influence on policy than a high quality piece of analysis that arrives 6 months too late. Researchers need to be aware of how policymaking works in order to design approaches accordingly. Decision-analytic frameworks (e.g., decision analysis, cost–benefit analysis, cost-effectiveness analysis, and cultural prescriptive rules) can be used to bring evidence together to assess trade-offs (Watson, 2005).

Systems Mapping

One approach to contextualise evidence can be in developing systems maps, e.g., representing causal loops, or stocks and flows (Lane, 2016). This can take place as part of a participatory co-learning process, e.g., using workshops and interviews to build up a map (e.g., Lane, 2016; CECAN, 2019). It can also form part of a decision analysis approach. For example, Whitney et al. used expert elicitation to form a model of social, economic, political and environmental factors that affected nutrition in Uganda (Whitney et al., 2018b). The participatory approach that formed the model involved 23 experts answering questions over a week-long workshop.

A simpler approach could be the adoption of a linear conceptual model, such as the source-mobilisation-delivery-impact model developed for diffuse agricultural water pollution (Haygarth et al., 2005). In either case, evidence from research syntheses or models can be superimposed onto the map or conceptual model to link disparate pieces of research and to expose gaps. Expert elicitation, e.g., through Delphi processes, can be used to fill gaps and estimate uncertainty (Fischer et al., 2014; Whitney et al., 2018a).

Modelling and Decision Support Tools

A range of decision support tools, including frameworks, guidelines and models (De Ridder et al., 2007; Chazdon and Guariguata, 2018), have been developed to inform integrated landscape management. They have a range of different functions relevant to several of the different stages of policy or programme development shown in **Figure 1**. Such tools are particularly useful for scenario testing, targeting interventions, analysing trade-offs and synergies, and optimising solutions (Chazdon and Guariguata, 2018). They fall into categories including (1) Assessment frameworks, (2) Participatory tools, (3) Scenario analysis tools, (4) Multi-criteria analysis tools, (5) Cost-benefit analysis tools, (6) Accounting tools and indicator sets, and (7) Modelling tools (De Ridder et al., 2007). Sometimes simply informing decision makers on the existence and availability of tools can facilitate their uptake (Wood et al., 2018). The trade-off between the time required to use tools and the depth and quality of information they provide is a major factor affecting adoption (Bagstad et al., 2013). Hard or soft coupling of multiple biophysical, socioeconomic, and environmental models to evaluate complex systems offers a good deal of promise (Bagstad et al., 2013; Jones et al., 2017), as does combining macro-scale and sectoral models to identify specific intervention options within broader national or regional development scenarios (Allen et al., 2016).

Ecosystem Service Assessment Approaches

Approaches to identify and value ecosystem services can provide useful information to inform land management decisions (Carpenter et al., 2009; Primmer and Furman, 2012). A large number of tools and frameworks have been developed and applied to quantify and assess ecosystem services. These include ecosystem process models, ecosystem service models, integrated assessment models and ecosystem service valuation models, applicable at site (e.g., farm or town) or landscape (e.g., catchment or national) level (Bagstad et al., 2013; Wood et al., 2018). Such models can be used for scenario testing at every step of the policy cycle: exploratory scenarios at the *agenda setting* phase, target seeking scenarios at the *design* phase, ex-ante policy screening scenarios at the *implementation* phase and ex-post policy evaluation at the *review* phase (IPBES, 2016). Ecosystem service assessments have been applied from local to global scales and in many contexts.

Ecosystem service tools are very variable in their type and usability. Grêt-Regamey et al. (2017) evaluated 68 such tools. Most have been designed and applied in developed countries where spatial environmental data is relatively rich. They allow users to explore the impact of land management scenarios on one or more ecosystem services. The format of these tools is highly variable, for instance including interactive pdf documents, empirical models, or process-based models, available online or as standalone computer programmes. Some are spatially explicit, others not. Accessibility is also variable. Some tools are publicly accessible, others are described as prototypes. Some have user-friendly front-ends whereas others require users to be skilled in coding.

Tools need to be matched carefully to a given application (Gasparatos and Scolobig, 2012; IPBES, 2016). Several authors have suggested criteria for the selection of ecosystem service models and decision support tools, e.g., including the decision context, values of stakeholders, key ecosystem services, and time and funds available (e.g., Gasparatos and Scolobig, 2012; Christin et al., 2016).

IPBES has published guidance on how to apply ecosystem service assessments for policy (IPBES, 2016), and various models have been well-tested in a policymaking setting. For example, the Natural Capital Project has applied the InVEST model in a large number of case studies. This includes policy development in the context of spatial planning, payments for ecosystem services, impact assessments for development permits, hazard mitigation, adaptation to climate change, land restoration, and corporate risk management (Ruckelshaus et al., 2015). Other ecosystem service models have been applied to a variety of policy sectors, particularly including spatial planning, agriculture, water, conservation, forestry, soil and climate (Grêt-Regamey et al., 2017). These applications have varied in the level of policy engagement and the influence of the evidence generated.

Current ecosystem service assessment methodologies suffer from a number of limitations: (1) a lack of land cover data and relatively simplistic approaches limit spatially explicit recommendations, (2) uncertainty is rarely quantified, (3)

TABLE 3 | Proposed decision support framework for knowledge brokering in integrated landscape management.

		Guiding questions:	Examples of approaches and data sources

Component 1: Situation analysis	1a Stakeholder engagement	• Who are the key stakeholders?
		• What are their goals and connections?
		• Who are the main investors?
		• What are the political/ economic constraints facing the programme?
		• What are the windows of opportunity for action (new investments, programmes, policies)?
			• **Workshops, interviews, questionnaires and reviews** to:
			  • Map key stakeholders (e.g., using Influence and interest matrices; Young et al., 2014) **(D/P)**
			  • Capture stakeholders' goals (**D/P**)
			  • Map existing policies, programmes and interventions **(D/P)**
			  • Characterise the political and institutional environment **(P)**

	1b Problem framing	• What are the main objectives of your programme or policy? • What is the geographical scope for your programme or policy? • What are the priority (SDG) outcomes for the region and landscape? • How do these priorities vary between different interest groups? • What are the external risk factors that may affect priority outcomes? (Climate, weather, pests, diseases, economic trends, social and political factors)	• **Review of local data** and evidence **(R)** • **Scene setting workshops:** Multi-stakeholder participatory priority and value mapping to define core objectives and identify priority development outcomes **(P)** • **Local scale focus groups or citizen assemblies** to capture needs and aspirations of communities and identify potential limiting factors **(P)** • **Application of holistic frameworks** to cover multiple outcomes (e.g., Sustainable Development Goals or ecosystem services) **(M)** • **System mapping** (e.g., causal loop mapping, systems dynamics modelling, material flows analysis) **(M/P)** • **System appraisal** e.g., five whys, fishbone diagram, force field diagrams, influence and interest matrix (Young et al., 2014; ODI, 2019) **(P)** • **Climate Smart Agriculture prioritisation framework** (Girvetz et al., 2017) **(M)** • **Rapid Appraisal of Agricultural Innovation Systems** (interviews workshops and questionnaires) (Schut et al., 2015) **(D/P)** • **Convene decision analysis team** (experts, stakeholders) **(P)**
Component 2: Prioritising interventions	2a: Targeting key groups and geographies	• What are the key risks that need to be taken into account from a social, economic and environmental perspective? • Which parts of the landscapes are most vulnerable to these risks? (Soil type, elevation, slope, geology, hydrology, precipitation) • What types of farm/household or population groups need to be targeted? • What other landscape factors need to be taken into account in targeting interventions? (e.g., watershed, air-shed, food-shed, habitat connectivity, climate change) • What are the potential (positive and negative) impacts on non-targeted groups?	• **Land typologies:** based on physical characteristics and land potential (e.g., CEH Dynamic Landscape Typology CEH, 2018; FAO Land Utilization Type FAO, 1996) **(M)** • **Household/farm typologies:** e.g., (Goswami et al., 2014) **(M)** • **Assessment of priorities by social groups** (e.g., women, youth) **(D/P)** • **GIS layers:** Land cover (Eigenbrod et al., 2010); Soil type e.g., (Fischer et al., 2008)[a]; Digital Elevation Models; Hydrology; Geology; Precipitation; Ecology **(R/M)** • **Risk maps** (e.g., mapping soil erosion risk, exposure of water resources, hydrologic and hydraulic modelling, etc.) **(M)** • **Participatory approaches** to capture local knowledge **(P)**
	2b: Screening SLM technologies (land, water and ecosystem management interventions)	• Which SLM technologies / land management practices exist to tackle the priority outcomes for your target landscape? • What effect do they have on each of the priority outcomes identified in step 1? How does this effect arise? Through which biophysical and socio-economic mechanisms? • How much do they cost and who pays? • Which farm and land types is the approach applicable to? • Which interventions are supported by evidence? • How strong is the evidence supporting each of the interventions? • How relevant is the evidence to the current setting? • Where are the evidence gaps?	• **Review of option databases** (e.g., WOCAT, 2019)[b] **(R)** • **Develop/review evidence syntheses** (e.g., Conservation Evidence; Sutherland et al., 2019) **(R)** • **Literature review** including systematic reviews and systematic maps **(R)** • **Review farm survey data (R)** • **Expert elicitation** to fill evidence gaps and assess practices against multiple criteria **(P)** • **Vision and scenario development** of different agricultural and resource management practices (Li et al., 2010; Chen et al., 2018) **(P)** • **Marginal Cost Curves** to assess cost and benefit (Chukalla et al., 2017) **(M)** • **Modelling of option efficacy** including *systems models* (e.g., IMPACT, PODIUM, WEAP, SOURCE, MIKE); *crop models* (e.g., GAEZ, DSSAT, EPIC); *energy models* (e.g., MESSAGE, LEAP); *integrated assessment models* (e.g., those summarized by the IPCC), *ecosystem service models* [e.g., Landscape IMAGES framework (Groot et al., 2007), FarmDESIGN]; *farm trade-off models* [e.g., FARMSCOPER (Gooday et al., 2014, 2015)] **(M)** • **Collection of new survey data** (D) • **Field based experiments** (plot, field, farm and landscape-scale research) **(D)**

(Continued)

TABLE 3 | Continued

		Guiding questions:	Examples of approaches and data sources
Component 3: Programme design and implementation	3a: Planning policies and programmatic interventions (SLM Approaches)	• How would one encourage uptake of each approach (policy mechanism)? • What is the predicted uptake by each farm type? • Which policy levers are best to target: • Particular land management practices? • Particular social groups? • What are the risks and side-effects of interventions? (Social equity, political interference, economic) • Who is likely to be affected in adjacent non-target locations/sites, population groups and communities, positively or negatively?	• **Review of social data** on attitudes **(R)** • **Bayesian networks** to predict the factors influencing uptake of new practices (Moglia et al., 2018). **(M/P)** • **ADOPT tool** (Kuehne et al., 2017) **(M)** • **Experimental games (P)** • **Collection of new survey data (D)**
	3b: Implementation	• What resources are available to implement? (Funds and people) • Who are the most appropriate actors to implement the SLM approaches (2c) to encourage uptake of the technologies (2b) by the right people in the right places (2a)? • What resources do they need? • What are the risks to delivery?	• **Workshops** to test proposed approaches with key actors (P) • **Resource mapping (R)** • **Piloting (D)** • **Citizen science (D)** • **Programme management and planning techniques** • **WOCAT toolkit action planning module** (Bastidas Fegan, 2019)
Component 4:	4: Monitoring and evaluation	• What are the expected outcomes? • What are the observed outcomes? • How should the policy or programme be adapted?	• **Ex ante evaluation approaches** (HM Treasury, 2011) **(M)** • **Field data collection (D)** • **Deployment of monitoring and sensor networks (D)** • **Earth observation (R)** • **Surveys (D)** • **Simulation modelling (M)** • **Ex post evaluation (D/M)** • **Crowdsourcing (D)**

Approaches are marked as follows: (P) participatory approaches, (R) evidence review approaches, (M) models, frameworks and decision support tools, and (D) protocols for the collection of new data (surveys, monitoring protocols etc.). Examples of approaches are provided in the references shown.
[a] Soilgrids.org Available online at: soilgrids.org (accessed August 29, 2019). [b] CCAFS Agtrials. The Global Agricultural Trial Repository and Database. CGIAR Res. Program. Clim. Chang. Agric. Food Secur. Available online at: http://www.agtrials.org/ (accessed August 26, 2019).

relatively few are able to account for the demand for ecosystem services and their valuation, (4) many miss key services, and (5) they do not account for political and organisational aspects of decision making (Grêt-Regamey et al., 2017). A shortage of technical skills, lack of understanding about the benefits of ecosystem service modelling, lack of interaction between scientists and policymakers and a lack of guidance in model choice also limit the uptake and use of these types of tools (IPBES, 2016). Finally, models can be biased towards the biophysical rather than socio-economic aspects of socio-ecological systems (Rossing et al., 2007).

Partly because of the reasons set out above, ecosystem service models can generate results that lack relevance to policymakers, needing further work to contextualise them (Grêt-Regamey et al., 2017). Other authors have found little evidence of uptake and use of ecosystem service models. An analysis of 22 case studies in Europe and Latin America found that although most had engaged a wide range of stakeholders, there was little evidence that ecosystem service knowledge had been used systematically to select policy options (Saarikoski et al., 2018). Several authors have therefore suggested ways of embedding ecosystem service assessments in participatory processes that take into account the values and knowledge needs of different stakeholders (Förster et al., 2015; Martinez-Harms et al., 2015; Neufeldt et al., 2015; Rosenthal et al., 2015; Ruckelshaus et al., 2015; IPBES, 2016). Used in this way ecosystem service assessments can support conceptual learning between researchers, practitioners and stakeholders (IPBES, 2016; Saarikoski et al., 2018) and can be effective for informing policy change and integrated landscape management (Ruckelshaus et al., 2015).

A PROPOSED INTEGRATED LANDSCAPE MANAGEMENT EVIDENCE FRAMEWORK AND TOOLKIT

One way to make evidence more accessible and usable to policymakers is to provide guidance on which combinations of approaches can be used to answer particular types of policy question.

In **Table 3** and **Figure 2**, we set out the blueprint for a "toolkit of toolkits." This provides the structure for a future database of evidence sources, decision support tools and participatory approaches to inform decisions at each of the seven integrated landscape management stages set out in the section on Decision Making in Integrated Landscape Management. Each of the seven parts can act either as a standalone toolkit to address specific challenges or as part of a holistic toolkit that can be used in its entirety to guide decision makers through policy or programme design as a learning cycle. Although **Figure 2** is presented as a cycle, there is no set starting point, and sections do not necessarily need to be followed in sequence.

The framework aims to provide a signposting tool to guide knowledge brokers and decision makers in the selection of the most appropriate evidence sources and analytical approaches to use for policy and programme design. We envisage this as a toolkit that is used by researchers, knowledge brokers and policy advisers to provide more holistic and responsive advice to integrated landscape management decision makers.

Table 3 sets out guiding questions for each of the seven stages. We also present an illustrative list of evidence sources, decision support tools and methodologies that can be used at each stage. These include (1) participatory approaches, (2) evidence review approaches, (3) models and decision support tools, and (4) protocols for the collection of new data (surveys, monitoring protocols etc.). The list is not intended to be definitive and the most appropriate choices are likely to vary significantly between different places depending on geographical factors and programme goals. Those selected and applied will also depend on time availability (e.g., rapid expert elicitation approaches vs.more in-depth, analytical ones), access to expertise, funding,

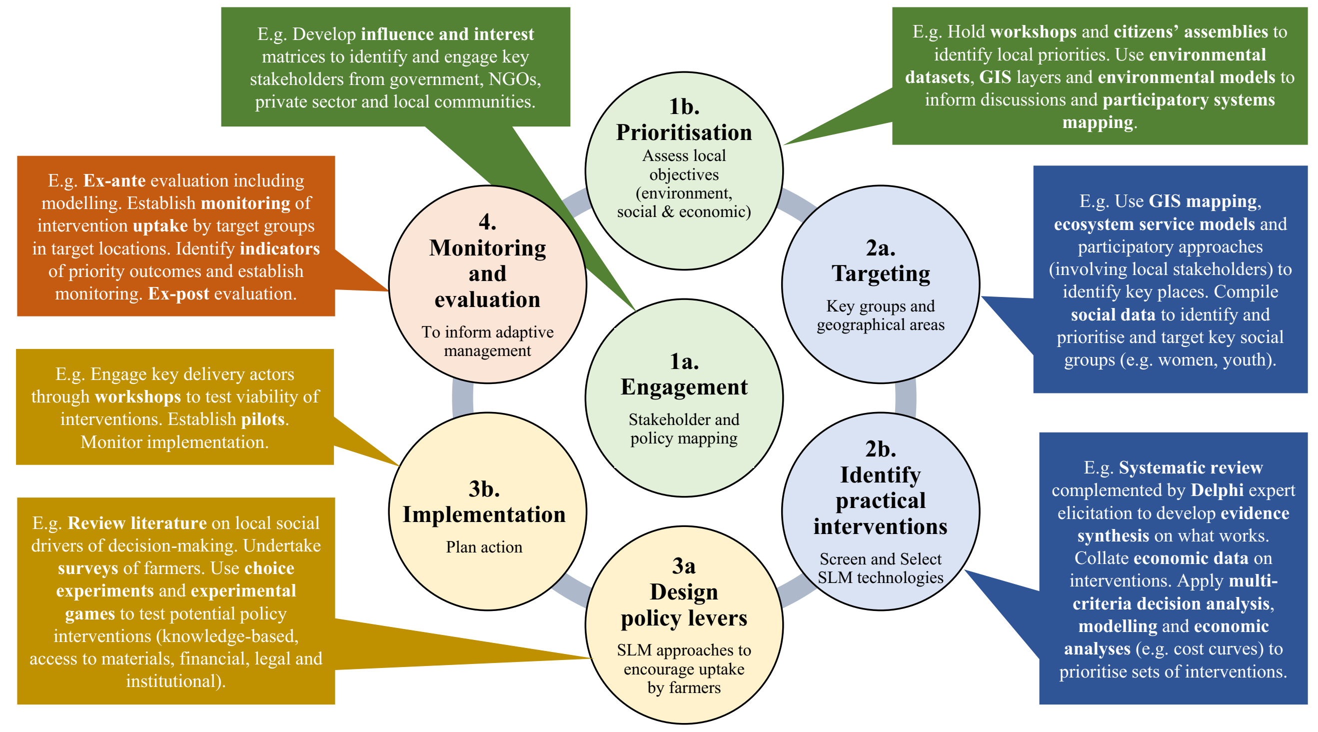

FIGURE 2 | A knowledge brokering toolkit for Integrated Landscape Management: Examples of approaches to synthesise and apply evidence to inform seven types of policy decision relating to integrated landscape management.

TABLE 4 | Ten proposed principles for knowledge brokering in integrated landscape management and 12 key skill-sets for knowledge brokers.

Principles	Skills
1. **Ongoing science-policy dialogue:** to understand demand, context and windows of opportunity when policymakers are likely to be receptive to evidence. 2. **Take account of context:** including broader socio-economic, cultural, and political factors that influence decision-making. 3. **Transdisciplinarity:** engage researchers from multiple disciplines alongside policy stakeholders and communities. 4. **Co-design policy and programmes:** involving researchers and stakeholders. 5. **Co-develop research:** engage decision-makers in evidence generation. 6. **Draw on evidence from multiple actors:** researchers, practitioners, stakeholders, local people, policy makers. 7. **Make use of all types of information available:** qualitative and quantitative data, research findings, observational evidence, process theory, models, local/ indigenous knowledge. 8. **Weight evidence:** Take account of uncertainty, bias and the strength of evidence. 9. **Use the right tools for the job:** Guide and support decision makers in the selection of tools and approaches that are appropriate to their questions and context. 10. **Pragmatism and timeliness:** A timely but partial response is likely to be more influential than one that is too late.	**Facilitator mode:** 1. **Facilitation** 2. **Communication** (balancing clarity vs. complexity) 3. **Building networks and collaboration** **Policy mode:** 4. **Knowledge of institutions and political process** 5. **Knowledge of policy design and implementation in local context** (understanding the context for evidence use) 6. **Capacity development** **Researcher mode:** 7. **Broad subject matter knowledge** (knowledge brokers don't need to be an expert in everything but need credibility) 8. **Evidence synthesis** 9. **Expert elicitation** 10. **Systems research approaches** 11. **Research and evaluation design** 12. **Interpreting, evaluating and weighting evidence**

data availability, and level of precision required as follows:

- **Rapid response approaches (3–6 week timeframe):** where time, data, funds, or other resources are limiting. Approaches are likely to mainly rely on rapid evidence assessment supplemented by participatory expert elicitation approaches.
- **In-depth approaches (3–6 month timeframe):** a more comprehensive approach where time is less limited. This is likely to involve more detailed desk-based literature reviews, and the application of existing models and decision support tools.
- **Full assessment (1 year + timeframe):** drawing on the full array of desk and field approaches where time and resources allow. Including the approaches set out above plus the collection and analysis of new empirical data.

CONCLUSION

Knowledge brokers working on integrated landscape management need to draw on a wide range of different approaches, evidence sources, and skills in order to translate research into actionable policy. They need to work in research-mode, helping to synthesise and contextualise fragmented evidence to *inform* policymaking, and in facilitator mode, bringing together experts from different disciplines with stakeholders from multiple interest groups to co-develop a shared systemic understanding (*collaborating* and *building capacity)* (**Table 2**). **Table 4** sets out some of the key principles and skills for integrated landscape management knowledge brokers that we have drawn from the literature.

There will never be time to develop a perfect understanding of the complex socioecological interactions affecting integrated landscape management programmes and policies. Decision makers need support to make the best use of available evidence there is. Pragmatism and timeliness are key. Evidence syntheses need to be used in conjunction with models and participatory expert elicitation approaches.

The knowledge brokering process is admittedly challenging and has many potential conflicts. We offer guidance on how to make better use of evidence in the design of integrated landscape management policies and programmes. We recognise that a wide range of factors apart from evidence influence policy decisions. Amongst other things, these include politics, power dynamics, public opinion and organisational structures. The approaches that we present need to be applied within the context of these factors. Although the roles of politics and power dynamics are outside the scope of this paper, they have been explored by other authors (Estrada-Carmona et al., 2014; Milder et al., 2014; García-Martín et al., 2016; Zanzanaini et al., 2017).

It is clearly critical that community-based transdisciplinary approaches explicitly include relevant stakeholders. Decision-makers are often those with power and engaging with them should not lead to the exclusion of those without power. We should seek to include the knowledge, values and opinions of those affected by the issues together with those of scientific experts and decision makers (Funtowicz and Ravetz, 1994; Wilson et al., 2007). Participatory mapping, evidence synthesis and decision analysis approaches can all be employed in helping to achieve this.

The decision support framework presented here (**Figure 2** and **Table 3**) aims to map types of evidence and approaches onto the different types of questions facing integrated landscape management decision makers. The framework set out in this paper will be populated and tested over the next 3 years through the CGIAR Water, Land and Ecosystems flagship programme on Enhancing the Sustainability of Agriculture.

The value of knowledge brokering is widely recognised but its provision is currently *ad hoc*. There is a need to formalise and strengthen capacity in knowledge brokering, recognising it as a specialism in its own right, and developing appropriate incentive structures and career pathways. For example, universities can offer training programmes aimed at equipping students with the skills needed for systems research. Research organisations can create knowledge brokering roles in order to maximise the impact of their work. Policy organisations and NGOs can build their own capacity, equipping scientific advisers with skills in networking, communication, facilitation and systems research alongside their traditional skillsets as subject matter experts in their own right. This requires a conceptual shift in the way that evidence is created, accessed and used. Research funders can also help by recognising the value of co-created, transdisciplinary approaches.

AUTHOR CONTRIBUTIONS

The paper sets out ideas developed during the planning phase of the CGIAR Water, Land, and Ecosystems flagship programme on Enhancing the Sustainability of Agriculture. The toolkit concept set out in **Figure 1** was developed by DM based on discussions with the team. Literature searches and summaries were undertaken by GN and RP. Text was written by DM, GN, and RP with inputs from the wider team. All authors contributed to manuscript revision, read, and approved the submitted version.

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