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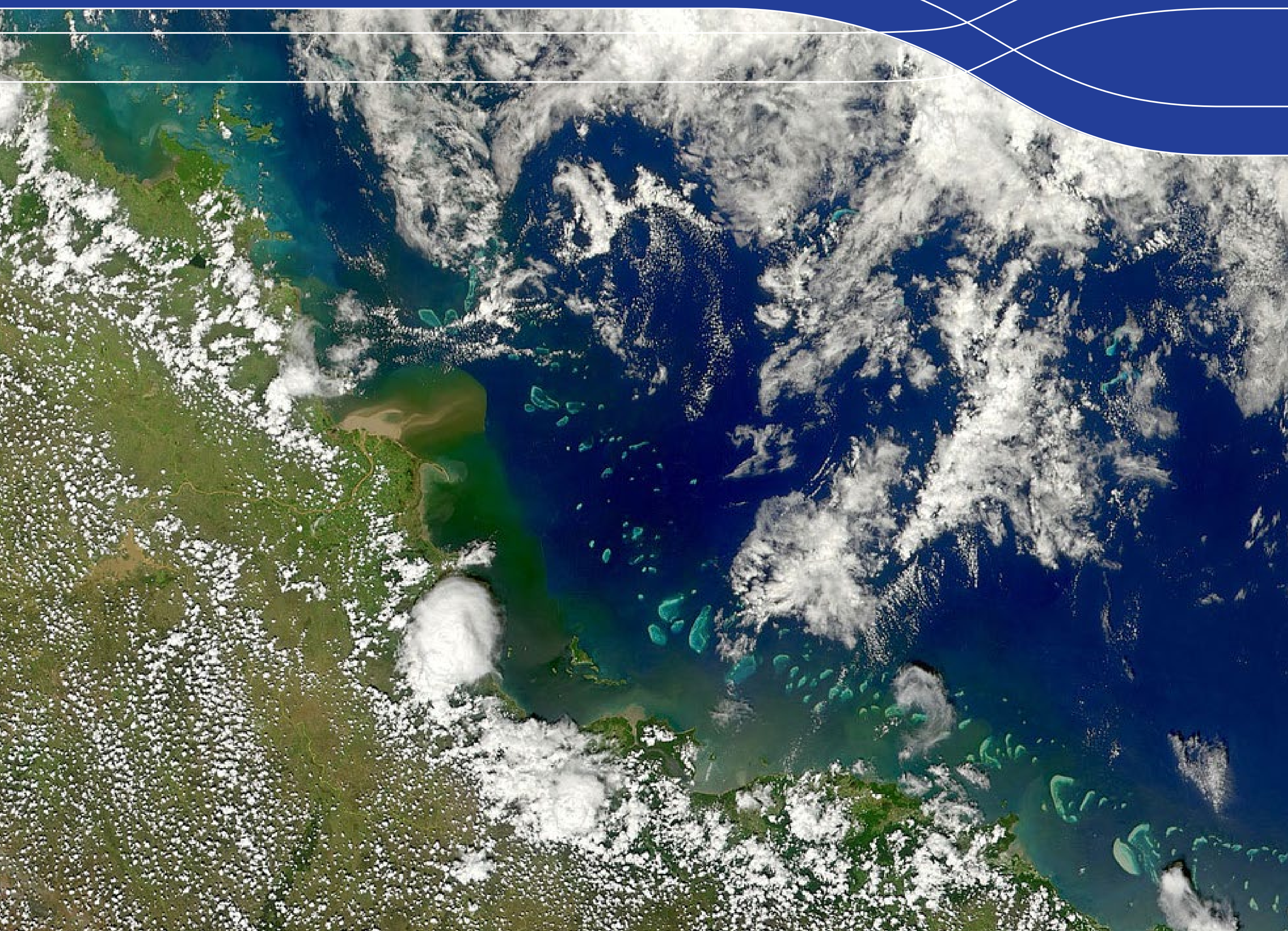
The Great Barrier Reef

Using our unique interdisciplinary partnership approach to work with government, researchers and the community to ensure a sustainable future for the Great Barrier Reef.



Integrated modelling to inform practice change and policy making in the Great Barrier Reef region

The Great Barrier Reef (GBR) is under increasing pressure from climate change, poor water quality from landscape runoff, impacts from coastal development, illegal fishing and to some extent tourism. The reef has lost more than half its coral cover since 1985, with increases in sediment and nutrients linked to declines in water quality (WQ), seagrass and hard and soft coral cover[1].

In response to the increasing, combined pressures on the GBR, State and Federal governments are investing significantly into the protection of the reef. The Reef 2050 Long-Term Sustainability Plan focuses on halting or reversing the decline of water quality entering into the GBR lagoon. Despite investments into targeted end-of-catchment monitoring to track progress, the disparate spatial and temporal nature of sampling is such that it would take at least 50 years to quantify trends towards a 20% loads reduction at end of catchment sites like the Tully and the Burdekin using monitoring data alone[2]. Hence monitoring is complemented by the use of models that describe the dominant processes and interactions between them at varying spatial and temporal scales.

Models are important for prediction, forecasting and testing future scenarios under changing climate and land use combinations. Models can also be used as integration and learning tools to help build credibility and trust with stakeholders. They can help them understand how processes change under varying climatic conditions or how a potential practice change on the land might impact a section of the reef through changes in sediment and nutrient delivery, as well as co-developing scenarios and modelling questions with stakeholders. Models also have a role in informing monitoring programs, such as the Reef Integrated Monitoring and Reporting Program (RIMReP). For instance they can help quantify the uncertainty captured in data – whether remotely sensed, sensor data, in-situ or expert based.

Modelling responses to date

A range of modelling tools are being utilised to bridge the gap between what processes are happening on the the land and to inform how this can potentially impact the GBR. An overview is given in Table 1. These models span across three spatial scales and attempt to capture the underlying processes within each.

TABLE 1. OVERVIEW OF THE MAIN MODELLING TOOLS BEING USED IN GBR RESEARCH

Model	Scale	Framework	Outputs
APSIM, How Leaky, GRASP (as part of Paddock to Reef - P2R[3])	Point/paddock	Point/hillslope scale process models to evaluate options for practice changes in grazing (cover) and cane management (nitrogen).	Feeds into Source model to determine end-of-catchment outcomes for land use or practice change.
Source (as part of P2R)	Catchment	Determines end-of-catchment sediment and nutrient loads.	Primary Queensland Government reporting tool to track progress across all GBR catchments. Used also as an investment prioritisation tool.
eReefs	Marine	Novel modelling platform that uses meteorological and catchment forcing to predict water quality and ecological state over time.	Provides the best estimate of present water quality state for reporting, and to quantify the improvements obtained through management strategies.

Issues and gaps

LACK OF RELEVANCE TO LANDHOLDERS –

Currently there are no appropriate models being used in the GBR that inform enterprise decision trade-offs at a cane enterprise or grazing property scale. Existing paddock models only capture a small subset of practices and decisions and do not place these into the context of overall enterprise decision making. Hence modelling outputs from paddock scale models are only partially relevant to land managers. At the catchment scale, from a landholder's perspective there is a spatial and temporal disconnect between practice change at a point in time within a paddock, and the ability to observe responses in catchment and reef models. This therefore makes end of catchment model outputs difficult to relate to farmer decision making and diminishes their value as an adaptive learning tool.

CREDIBILITY –

While model credibility is generally high with government stakeholders, it is low in stakeholder segments that affect agricultural practice change. There are several reasons for this. Lack of relevance and spatial and temporal disconnect between practice and response discussed above is one important cause. This is exacerbated by insufficient levels of engagement between modellers and landholders. Models are constantly updated to incorporate new process understanding. Often, these changes are not well documented or communicated, so that the ensuing lack of transparency also affects model credibility within other stakeholder segments (ie government and research). In addition, many stakeholders do not have a clear line of sight to what and whose data is used and what are some of the underlying assumptions and limitations of the model being proposed.

UNCERTAINTY –

Reporting uncertainty is one aspect of modelling to help instigate credibility and highlight where a model works and where it breaks down, but currently it is not well presented in modelling results. Furthermore, where it has been quantified, it has not been appropriately communicated (if at all). Given the high temporal and spatial variability of flows and WQ there is also a greater need to capture the uncertainty inherent in both modelling and monitoring environments to convey the level of confidence that can be placed into the predictions, forecasts and scenarios arising from the modelling. It is important to recognise that different monitoring approaches yield error and data is not the truth. Providing measures of uncertainty captured in the data, whether remotely sensed, sensor data, in situ or expert based enables stakeholders to identify where to monitor, where to engage and where to repair. More targeted monitoring regimes can be put into action to deliver new information that is relevant for the modelling, underpinning new initiatives such as RIMReP.

EVALUATING CLIMATE CHANGE PROCESSES –

While the current suite of models generally capture the basic processes affected by changes in climatic parameters (temperature, CO_2, rainfall), they have not yet been used to systematically evaluate the impacts of climate change on the changes in land use being sought.

BETTER PROCESS REPRESENTATION –

All models are being constantly improved. Nonetheless, there remain several key domains where significant improvements to process representation are warranted. Within the Source catchment model there is a need to better represent landscape hydrology (including ground water) as the driver of all erosion and nutrient transfer processes, and to better capture recent progress in gully erosion process understanding. Within eReefs, there is a need to improve the ecological responses of key marine ecosystems to changes in bio-geochemical processes. Finally, there is gap in the representation of processes relevant to climate change in the current suite of models (i.e. improved representation of temperature responses, implications of sea-level rise, integration of regional scale meteorological scenario modelling, carbon dioxide fertilisation on plant dynamics, implications of changing carbon chemistry, storm damage, etc.).

SCALE –

Linked to the issue of process representation is the question of scale. Unresolved questions include how do we evaluate models with data relevant to the time-scales of application; can we broaden the range of scales for which models are suitable (i.e. catchment models including processes needed for daily time-step operation; marine models operating faster to allow multi-decade scenario operation); and what time scales are appropriate for the different types of models and types of decisions being sought?

Opportunities

A number of recent research advances and new policy initiatives open opportunities to significantly enhance the existing modelling framework in Table 1.

A new generation of bio-economic models has been developed and successfully applied at the farm household and enterprise scales in other contexts. These include sectoral trade-off analysis tools such as Northern Australia Beef Systems Analyser, that enable an evaluation of how different mixes of grazing enterprise activities affect economic, production and environmental outcomes[4], or a range of applications based on Interactive Multiple Goal Linear Programming (IMGLP) that optimise for multiple socio-economic or policy outcomes defined by stakholders[5]. These tools can conceptually be quite easily modified to suit the context of cane or grazing enterprises, including the ability to segment farms into multiple management units.

The intent of the Queensland Government to fund two major improvement projects (MIP) in the Wet Tropics and Burdekin offers a unique entry point to (re-)engage with cane growers and graziers to demystify modelling, and if linked to local monitoring, to develop greater trust and relevance of modelling to landholder decision making and practice change[6].

Major advances in visualisation of model outputs in eReefs also provides useful insights and techniques to support better visualisation of outputs in other modelling domains. Coupling better resolution of uncertainty to these improvements in visualisation could add significant additional impetus to increasing stakeholders' confidence in modelling results.

Finally, relevance of and confidence in models could also be further increased by incorporating recent progress in process understanding. Three domains where this is warranted comprise improved understanding of gully erosion dynamics[7], grazing landscape hydrology[8] and marine ecosystem responses to changes in water quality[9].

Integrated modelling

Building on the existing modelling frameworks comprising P2R and eReefs, our vision, represented conceptually by Figure 1, is to develop an integrated modelling framework that responds to the opportunities outlined above, with state-of-the-art, fit-for-purpose process representations of all the dominant processes and interactions between paddock, enterprise, catchment and marine environments. Importantly, the integrated modelling framework needs to incorporate management actions and their responses in both the biophysical system and farm scale economics. These models would need to be assimilated with remote sensing and monitoring datasets to establish a robust, consistent and accurate baseline status for all relevant constituent stores, fluxes, interactions and impacts.

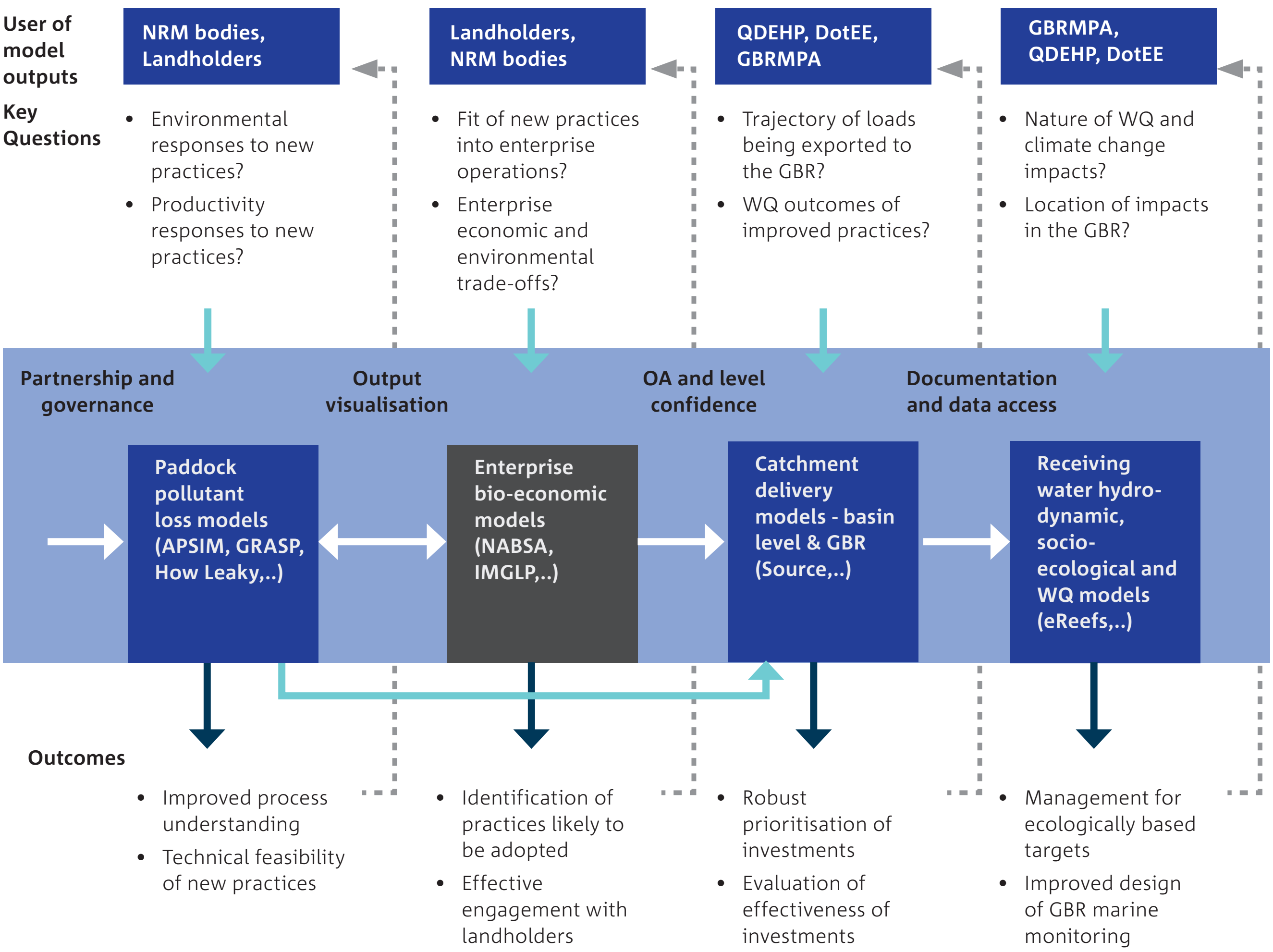
The design of this enhanced framework needs to be guided by clarity on who the main users of modelling outputs are, what the questions are that they want answered, and how answering these questions might lead to material GBR outcomes.

A major addition to the existing framework comprises enterprise bio-economic models (grey box), and the fact that there is an important feedback loop whereby paddock models can preselect potential practice changes, that are then evaluated with respect to feasibility and likelihood of adoption in the whole of enterprise context. A return loop to the paddock models with those practices likely to be adopted by landholders is then scaled up as input into the catchment model.

Embedded across all four models are several underpinning principles regarding modelling partnerships and their governance, greater focus on visualising of model results, quality assurance processes that are based on incorporation of uncertainty (i.e. level of confidence), and documentation and easy access to input and output data. Quantifying the uncertainty of the model parameters, forcing inputs and model structure are important for identifying where information is lacking or the model breaks down, across all scales. Thus modelling also helps with the identification of what type of data needs to be collected and where to collect it for reducing uncertainty and improving outcomes.

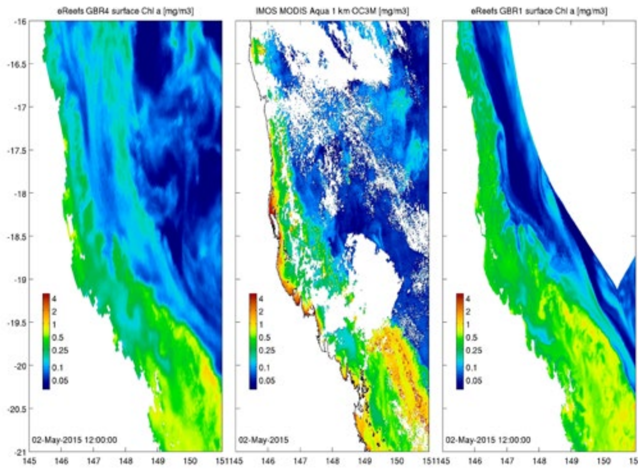
Within the marine waters of the GBR there exist a number of multi-species and end-to-end models that include the food web, key ecological processes, as well as the broad range of human activities (shipping, fisheries and other industries). As yet these link poorly with the catchment processes (typically only including load forcing). Given the interconnected nature of the coastal zone and surrounding catchments it is likely that management progress will ultimately run into barriers associated with the linkages. At that point a true catchment to coast framework would likely be needed to identify navigable pathways for further advances. For such a framework to usefully capture the key processes, there would need to be a much more effective representation of aspects of the ecology and broader socioecological system[10].

FIGURE 1. NEXT GENERATION INTEGRATED MODELLING FRAMEWORK FOR THE GBR



Virtual modelling networks

Implementing processes that build on the existing modelling arrangements and move us towards the framework outlined above transcend the capability of any individual research organisation. It requires the forming of more effective linkages and modelling partnerships that are aimed at co-ordinating the suite of interdisciplinary skills that are spread across multiple federal and state agencies as well as universities. An option is to form a virtual modelling network that develops agreed processes for continuous improvement and documentation of models, alongside routine reporting. To free up additional modelling resources, consideration should be given to reducing the current annual GBR Report Card cycle to a bi-annual process. Such a virtual modelling network also needs to more effectively engage with stakeholders to communicate what models do, what the modelling results mean and how they can (or cannot) be used.



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