Integrated catchment management rediscovered: an essential tool for a new millennium

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Abstract

New Zealand has a rich history of research on and management of the impacts of both natural and anthropogenic change on land and water resources. Early on, New Zealand recognised the value of whole-catchment studies as a means to quantify these impacts and at one time lead the world in such research. However, a combination of financial, political, institutional changes over the last 10-15 years has devalued this approach. For example, although the RMA recognises the general importance of managing resources on a catchment basis, the focal point of the RMA is on management of "downstream" effects of specific activities. Resource managers are often forced to make decisions about individual consents in the absence of good evidence about the long-term, cumulative impacts of these decisions. In many cases, they are forced to make these decisions in the near absence of any supporting environmental data. Furthermore, managers in different regions often face similar problems with little incentive or means to share information and experiences. Science providers who should be in the position of providing supporting information have, until recently, been directed to compete among themselves rather than cooperate to solve pressing problems that have both local and national applications. A wide variety of issues, including riparian management, wetlands restoration, water allocation, groundwater abstraction, and greenfields development, would benefit from an integrated approach to catchment management. Such an approach requires a cooperative effort among land owners, developers, managers, and scientists and a coordinated mix of process-oriented studies, environmental monitoring, and computer simulation.

Introduction

The focus of today's sessions is on "whakapai whenua" – improving the land – and in this panel discussion we will focus on selected innovations in Environmental Management Technologies and Systems that might be employed to this end. My charge this afternoon is to inspire you to think about the role of catchment management as a tool that should be used in our efforts to improve the land. Some may question whether catchment management is really an "innovative" tool. Haven't we employed catchment management approaches for decades? The answer would have to be yes. However, in New Zealand, advocacy of catchment-scale studies in support of resource management objectives has declined significantly, especially in the last decade. It is appropriate, therefore, to revisit this approach and consider what it has to offer as a tool for the next millennium.

What is integrated catchment management?

Integrated catchment management (ICM) can be thought of as both a research approach and as an organising philosophy. As a research approach, ICM recognises that the environment is a complex system of interacting resources – an "ecosystem" – operating within a landscape context. The landscape context that we most often consider is the catchment or watershed, in recognition of the central role of water as a critical resource and of catchments as a source of water. It is instructive to recall that it was not until relatively recently that scientists recognised the inherent power of linking research on water transport to research on material (i.e., nutrients and pollutants) transport across the land. This link has spawned whole new fields of research, such as environmental hydrology and biogeochemistry, that have provided powerful new insights into how nature works and how people affect those workings. Thus, the catchment approach has provided an essential framework in which to link research on physical hydrology with research on and management of, for example, water quality, soil quality, vegetation dynamics, and land use.

Figure 1 suggests that components of the system might be thought of as layers, much as in a GIS. The layers represent knowledge areas (e.g. soils and plants) which often interact within a component group. The groupings, as illustrated here, are not terribly important. They are only intended to illustrate that some knowledge areas (e.g., soil and plant sciences) tend to talk with each other more often than others (e.g., microbial ecology and highway construction). The important point is that each of these knowledge areas and each grouping potentially has something to contribute to the solution of important environmental problems. Overcoming the barriers of communication among groups – especially those that are more distantly related (e.g. ecology and civil engineering) – is critical to the success of an ICM approach..

Figure 1 also indicates that ICM research approaches are issue-driven. In fact, it is the issues (sediments, water, nutrients) that provide the common language – or perhaps better: the common currency – that allows various disciplines and groups to interact with one another. Thus, engineers, interest groups, hydrologists, and plant scientists may effectively interact with one another on the issue of sediment generation from roading activities. And finally, it must be remembered that the entire system is dynamic…constantly changing and rarely in steady state.

An ICM approach is essentially scale-independent. However, the approach recognises that while small spatial and temporal scales of consideration are easy to manage, large spatial and temporal scales of consideration are essential to understand the cumulative impacts of individual management decisions. Thus, as indicated in Figure 2, an effective ICM research approach provides an effective link from plot-scale experiments and specific consents to regional research and to the plans generated by regional councils. Simulation models are an indispensable tool in this exercise.

The conceptualisations of ICM as a research tool and as an approach to management are strongly intertwined. My presentation today focuses largely on the use of ICM as a research tool. However, the management context can not — and should not — be removed from this discussion. A fully-functional ICM approach would include a seamless interaction among knowledge generators, knowledge purchasers, and knowledge users (Fig. 3). These individual constituencies interact with one another through the processes of governance, consulting, and outreach. Taken together, these activities create an effective, integrated approach to management of the environment.

So to summarise, I offer the following definition of ICM research:

> *An approach which recognises the catchment or river basin as the appropriate organising unit for research on ecosystem processes for the purpose of managing natural resources in a context that includes social, economic and*

political considerations.

This is a deliberately broad definition. However, there is a key ingredient in this complex approach. Resource management in a catchment context inherently requires an integrated approach. This integration occurs in a variety of configurations: among science disciplines, across spatial and temporal scales, from science through policy, management, and education, and among knowledge providers, users, and purchasers. Effective management of the important environmental problems we face today requires integration among all of these interests.

There are clear connections between ICM as a research and management tool and the related concepts of integrated ecosystem management, integrated *environmental* management, and *sustainable* management; themes that have recurred throughout the three days of this conference. Integrated catchment management (ICM) and integrated ecosystem management (IEM) are complementary terms that together express a scale and a perspective of approach to address environmental issues. Integrated environmental management focuses on institutional and policy changes that will more effectively achieve outcomes which society has identified as desirable. Sustainable management focuses on effects that our current actions will have on future generations. To oversimplify, these approaches represent a continuum of philosophies and activities that ultimately link ways of understanding natural ecosystem processes to a view of our environment and our future that we believe to be desirable.

The New Zealand experience with catchment management research

New Zealand has a rich history of research on and management of the impacts of both natural and anthropogenic change on land and water resources. At an early stage, New Zealand recognised the value of whole-catchment studies as a means to quantify these impacts. During the period of the International Hydrological Decade (IHD)(1964–1975), the New Zealand landscape was subdivided into 90 distinct hydrological regions (Toebes & Palmer 1969; Toebes & Morrissey 1970). Ultimately 76 representative basins were established in 73 of the hydrological regions. The purpose of these representative basins was to provide basic information about the physical hydrology of New Zealand's landscape for use in planning, resource management, and environmental monitoring. A portion of these representative basins were designated as "benchmark" basins, in areas where land use was not expected to change. These benchmark basins anticipated the future need for reliable information to support state of the environment reporting. In a 1976 review of the international state of the art in basin studies, John C. Rodda (U.K.) remarked that "...New Zealand's network of representative basins provides the world's best example of a comprehensive national system of this sort." (Rodda 1976).

In addition to the representative basins, a series of approximately 10 "experimental catchment" sites were established at various locations throughout New Zealand. These catchments were established as focal points for process-oriented research. Most of these catchments operated for a period of about 15–20 years, into the 1980s, but are now closed. However, portions of some installations (e.g., Puruki at Purukohukohu) are still operational.

Following the IHD programme (1964–1975), a network of "land-use" catchments was established at about 10 locations throughout New Zealand. These catchments were established to examine the consequences of a variety of land-use changes (e.g., pasture, dairying, afforestation) on water resources. Most of these catchments operated for about 10 years, from the mid-1970s into the mid-1980s, although a few of these catchment studies are still active (e.g., Glendhu, Maimai, and Big Bush).

It should be noted that, while these various catchment research programmes provided state-of-the-art information for the purposes of traditional watershed management (e.g., drinking water supplies, flood risk analyses, low flow characteristics), these efforts only partially achieved true *integrated* management as defined above.

The decline of catchment management research in New Zealand

It is useful to review, briefly, how catchment research has changed in New Zealand since the IHD. I do this not to bemoan what has changed or been lost. Rather, I believe it is instructive to look back on those things that seemed to have worked well and those that did not, as guides to how we might think about acting in the future.

The sweeping changes in science infrastructure that began in the mid-1980s caused the demise of most of the IHD catchment studies. In the ensuing reorganisations, the institutional motivations and individual efforts required to keep these labour-intensive studies going, was lost. Furthermore, the emerging model of "market-driven" science and explicit competition among science providers, created an environment in which cooperative, long-term, integrated catchment research oriented to national needs was difficult to establish. To be sure, the climatic and hydrometric data network in New Zealand is of very high quality (Waugh 1992; Mosley *et al.* 1992). This database is of enormous value for studies of physical hydrology, such as regional flood forecasting and low flow predictions. However, there are very few places in New Zealand where such information is integrated with intensive studies of, for example, soil nutrient dynamics (e.g., carbon, nitrogen, and phosphorus cycling), ecosystem processes (e.g., above- and below-ground primary production, secondary production, and biomass decomposition), land-water interactions (e.g., riparian and wetland processing), or complex land-use impacts. In recent years, only three major integrated catchment research programmes have been established, in the Waipoa River basin in the erodible hill-country of the North Island's east coast, at Whatawhata near Hamilton, and at Mahurangi north of Auckland.

Important changes in the environmental regulation framework in New Zealand exacerbated the changes in science infrastructure. In particular, the Resource Management Act of 1991 (RMA) replaced the Water and Soil Conservation Act of 1967, which was widely viewed as one of the most progressive pieces of environmental legislation in its time (Poole 1983). This is not the time or place to debate the relative merits of the RMA in its present form or as it is proposed to be amended. However, it is relevant to note that, although the RMA is based on a philosophical foundation that explicitly includes an integrated approach to environmental management (Part II, Sections 5 and 6), the practical application of the act has not generated this integration, for two primary reasons.

First, the responsibilities for environmental management were decentralised to the regional and district councils. This is not necessarily a bad change. However, resources available to many of the councils are limited. Furthermore, of the various responsibilities delegated to the councils by the RMA, the most urgent requirement was to generate a series of policy and planning documents. Approximately 100 of these documents were proposed as of 1995. In her recent review of integrated environmental management in New Zealand under the RMA, Julie Frieder (1997) noted that this planning effort, while valuable, has left little time or effort to actually implement the concept of integrated environmental management. She continued that although these plans might not be perfect, it is time to get on with the job of implementing the purpose and intent of the RMA as opposed to simply exercising its individual provisions. Finally, it should be noted that although decentralisation of the responsibility for environmental management provides the opportunity for local control, there is no particular motivation to share information and experiences among the councils. Thus, unless there are individual efforts by council staff to cooperate in joint initiatives (e.g., Water Resources Group), there is a risk that councils will engage in redundant activities (reinventing the wheel) or in uncoordinated activities (inefficiency). In summary, with so much of their energy and resources devoted to planning and policy efforts, regional and district councils appear to find it difficult to provide more than guidance and in-kind support for narrowly-focussed research projects, much less for large-scale, integrated research projects.

Second, despite its philosophical foundation in integrated, sustainable management, the practical focus of the RMA is on impact identification and mitigation. In a world of limited resources and seemingly unlimited development pressures, resource managers are faced with the thankless task of having to make decisions about individual consents on short time frames and with a lack of good evidence about the long-term, cumulative impacts of these decisions. In many cases, they are forced to make these decisions in the near absence of any supporting environmental data at all. A typical response is to monitor the environment in the hopes that problems can be identified and dealt with. Certainly, monitoring is a potentially useful activity, but only if it has been clearly established *why* monitoring is needed, *what* needs to be monitored, and *how* much change is unacceptable. Even this, however, misses the central point: by the time monitoring identifies that a problem exists, it may be too late to change the problem, too expensive to fix it, or too hard to identify who is really at fault.

Rather than focus on impact identification, we need to focus on source area management. To do this effectively, we need data about the characteristics of the source areas, information about the way these source areas work (individually and collectively), tools to forecast how the impacts caused by changes to the source areas will accumulate in space and time, and information about how these changes affect and are affected by people.

Why rethink the integrated catchment management approach now?

There are a number of reasons why this is a particularly good time to rethink the utility of ICM approaches as a means to achieve New Zealand's environmental sector outcomes. First, a number of new technologies now exist that make it possible to acquire, store, and use data in ways that could only be dreamed of during the IHD. In particular, remote sensing in its various forms provides exciting new opportunities to acquire high-quality data about the environment over large spatial scales at a fraction of the cost that would be required to acquire the same data manually. For example, innovative combinations of remotely sensed data currently give us estimates of ground cover and biomass and may soon give us estimates of biomass quality that will provide an essential link to ecological studies of soil fertility, plant primary production, and nutrient export from catchments. Geographic information systems (GIS) make it possible to manipulate these data quickly, model complex interactions across landscapes, and display results in ways that are exciting and meaningful to end-users. Fast, efficient, and effective computer models of fundamental environmental processes (e.g., groundwater contaminant movement, storm runoff dynamics, forest growth) are regularly introduced and refined. These new technologies are now considered to be "off the shelf", practical tools that greatly facilitate our ability to think about environmental issues in terms of large spatial scales and long temporal scales.

Second, this is a good time to reconsider ICM approaches because the science infrastructure is changing once again. The Foresight Process in which we have all been engaged is beginning to generate new directions for interactions among end-users, science providers, and science purchasers (e.g., Environmental Sector Foresight Steering Group 1998). We don't yet know the details of these changes. However, it is clear that whatever new system emerges will be focussed on outcomes desired by New Zealand society and that achievement of these outcomes will require a cooperative, integrated effort.

Finally, it is time to rethink the utility of ICM, simply because it is needed. In a recent address before the New Zealand Water and Wastes Association, the Hon. Simon Upton, Minister for the Environment, identified ecosystem management as one of the four most pressing challenges facing us today (Upton 1998). These challenges are complex, affect large areas, and act over long time frames. We will never have the resources to study everything, everywhere. Nor is it realistic or desirable to think that one person or organisation should take sole responsibility for achieving a particular outcome. Under these circumstances, ICM efforts can provide focal points for effective and efficient collaboration on issues of regional to national importance. This collaboration must include an extensive and effective partnership among a wide range of contributors, including community members, industry, resource managers, scientists, and purchasing agents.

The future of catchment management in New Zealand: three examples

To illustrate how an ICM approach might be used in the New Zealand context, I offer three concrete examples. These are not the only examples that could be offered; they simply support points made elsewhere in this presentation.

Tasman/Marlborough

The Tasman and Marlborough districts are areas with a rich array of resources and a complex array of land uses, including native reserves, parks, recreation, plantation forestry, horticulture, dairying, viticulture, and municipal developments. In addition, this is one of the nation's most productive and important locations for near-shore marine farming. It is also an area were community values for the environment are high and where iwi interests are particularly strong. Two important issues (among several) are of interest to a broad cross-section of the population (Tasman District Council 1996; Penman 1998). First, this area is subject to perennial low flows as a consequence of particular climate, soil, and land use conditions. Allocation of water, especially in times of low flow, is an important and potentially volatile issue, as demonstrated by a recent Environment Court hearing on this matter (Environment Court New Zealand 1998). Second, near-shore fishing interests are increasingly concerned that land-based activities may have detrimental impacts on the productivity or quality of their harvests. An ICM framework is the ideal approach to address these issues because the components have complex interactions, are spatially distributed, and have long-term impacts that are socially and economically important. This is a good example of a case where a consortium of community leaders, industry representatives, resource managers, and science providers could address issues that are of pressing regional concern and that have the potential to be of national relevance.

Auckland Region

The Auckland Region is an area that is under intense pressure to accommodate a population that is expected to grow from about 1.1 million today to as much as 2 million by 2050 (Auckland Regional Growth Forum 1998). Perhaps 70% of this growth might be accommodated in the existing metropolitan area, but up to 30% would have to be accommodated by "greenfield" conversions. The Auckland Regional Council and various city councils have invested heavily in efforts to understand the potential impacts of this growth, sometimes within an ICM context. Research has tended to focus primarily on stormwater runoff and sediment deposition impacts in coastal and estuarine areas, largely because these are pressing issues that can be observed easily and for which engineered solutions may exist. There is increasing interest, however, in the potential for using non-engineered solutions that have complementary benefits such as protection of native biodiversity, enhanced value of ecosystem services, and improved quality of life for urban residents; themes that have been the subjects of several earlier presentations in this conference. An ICM approach would be an appropriate means to study the biophysical impacts of urbanisation and the interactions of these impacts with social and cultural aspects of urban life.

Waipaoa River

The Waipaoa Catchment study is an effort to understand important land use issues on a large spatial scale and over a long time frame (Trustrum *et al.* 1998; Gomez *et al.* in press; Trustrum *et al.* in press). The Waipaoa catchment is a rural area in highly-erodible hill country of the North Island's east coast. This catchment is one of the world's great natural laboratories for research on the spatial and temporal scale issues that are central to integrated catchment management. The nature of erosion processes in this area have created an unusual degree of detail in local terrestrial and marine sediments, which provide a means to unravel the response of this catchment to natural and anthropogenic perturbations that have occurred over the past 10,000 years. Past research in this area has illuminated the biophysical mechanisms that promote or impair slope stability and has generated guidelines and recommendations that are grounded in defensible research and that are socially, economically, and politically acceptable. Current research is focussing on the wider impacts of sediment generation and deposition under different land uses and lithologies. Future research will focus on links between sediment dynamics and the dynamics of carbon, nitrogen, and phosphorus in an ecosystem context. This ICM research is essential to understand how large-scale changes in land use impact fundamental environmental issues such as soil fertility, freshwater productivity and biodiversity, and coastal environmental quality.

Currently, efforts similar to those described above are underway elsewhere in the world (e.g., McMahon *et al.* 1994; Pickett *et al.* 1997; Gupta 1998; National Academy of Sciences 1998 a & b; Wittgren 1998). Thus, there are excellent opportunities to learn from and contribute to related programmes of international importance.

What must we do to make an ICM/IEM approach work in NZ?

There are a number of things we will need to do to promote an effective ICM approach to the major environmental problems we face.

1. It would be easy — and not particularly helpful — to say that we need more money to tackle these problems appropriately. The fact is that, in the current environment, we are unlikely to have more money. Rather, we will have to use our existing funding differently. An ICM approach can structure and coordinate participants in such a way that both financial and human resources are used effectively.

2. Science providers will have to be willing to do some things differently. Some activities that have been supported in the past may have to end or be substantially modified. We will have to be willing to change what we do (within the limits of our training) and where we do it (within the limits of our budgets).

3. Science providers also need to develop an ethos of improved cooperation. Some have suggested that selected CRI♣s should amalgamate. In a truly cooperative environment, institutional structures should not matter. However, if institutional structure and a competitive business model continue to interfere with effective cooperation to deliver the outputs that end-users and stakeholders need, then perhaps amalgamation should be considered.

4. Universities and CRI♣s should explore improved opportunities for cooperation on ICM projects, through shared graduate students. This is a situation in which all participants have the potential to benefit: CRI♣s obtain expertise to fill gaps fast-moving, emerging areas which they might not be able fill with existing staff, universities obtain a important link between education and "real world" issues, students obtain unique opportunities for education and training, and society benefits from a more effective ICM process.

5. Resource managers need to insist on completing the link between assessment of effects and sustainable management of the environment, as envisaged in the RMA. Assessment of effects is necessary, but not sufficient. By the time we are able to measure an effect reliably, it may be too late – Morgan Williams' "time bomb". Sustainable management won't occur without effective management of source areas. It is unlikely that resource managers will ever find themselves in the position of having all of the information they need about every location for which a consent is sought. However, if they actively participate in efforts to identify key issues within an ICM framework, even when progress on these issues might not be done in their backyard, they should still find that valuable information emerges which can be used to intelligently inform their consent decisions. Furthermore, it is critical that they exercise the option to include *and impose* conditions on consents and develop means to monitor compliance, to establish the source-effects link.

6. Central government agencies need to accept that ICM approaches are an efficient and effective means to achieve certain nationally important outcomes. In particular, as FRST and other agencies deliberate over how to react to the recommendations of the Foresight Process, they should consider their roles as the *brokers* of national expertise about the environment, in addition to their roles as simple *purchasing agents*. Without strong central government support, it is hard to imagine that effective ICM applications will emerge from simple grass roots activities alone. A more effective means of establishing such efforts would be by deliberate support, in which central government takes a leading role.

7. It is clear that foreign consumers are taking increasing interest in the wider environmental impacts of the activities of New Zealand industry – a message brought home to us by Richard Riddiford of the Living Wines Group, at our conference banquet last night. An ICM approach provides an effective vehicle for industry to demonstrate its participation in the process to identify and minimise these impacts. New Zealand industry has the potential to make important contributions to ICM efforts through increased direct support of relevant research, science, and technology efforts, through in-kind support, and by simply participating in the process of identifying and working on coordinated solutions to major environmental issues.

8. Purchase agents of all sorts (local to central government) need to recognise that effective ICM efforts require the availability of high-quality, national databases of important environmental characteristics. These databases are important in their own right as sources of information for state of the environment reporting and for assessment of impacts that develop over a long-term. They are also essential as input or verification data for simulation models developed in conjunction with ICM field efforts. It is these models, and the databases that support them, that ultimately provide links between ICM sites and other unmonitored sites and between the present and the various expectations we have about our future. Development of these databases will of necessity be an incremental process. Maintenance and support of these databases should be coordinated nationally.

9. Finally, it is essential that we develop a means to include communities in the processes of science, management, and policy. After all, our ultimate goal is to solve problems and achieve outcomes that society deems to be important. The ICM approach is ideally suited to this goal because the unit of study — a catchment or basin — always has an associated community of stakeholders, either as residents or users. The challenge is to substantively involve this community in the development of ICM projects and to effectively transmit to them the results of such projects, so the targeted outcomes are in fact achieved

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Fig. 1 ICM as research framework

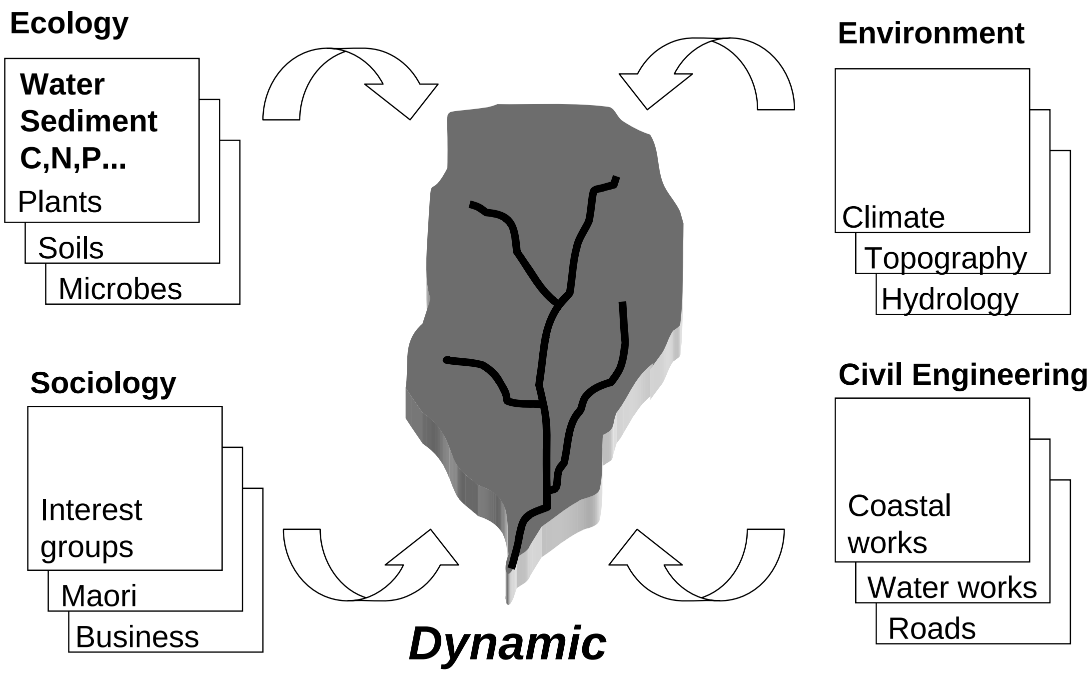

Fig. 2 ICM as a spatial-temporal link

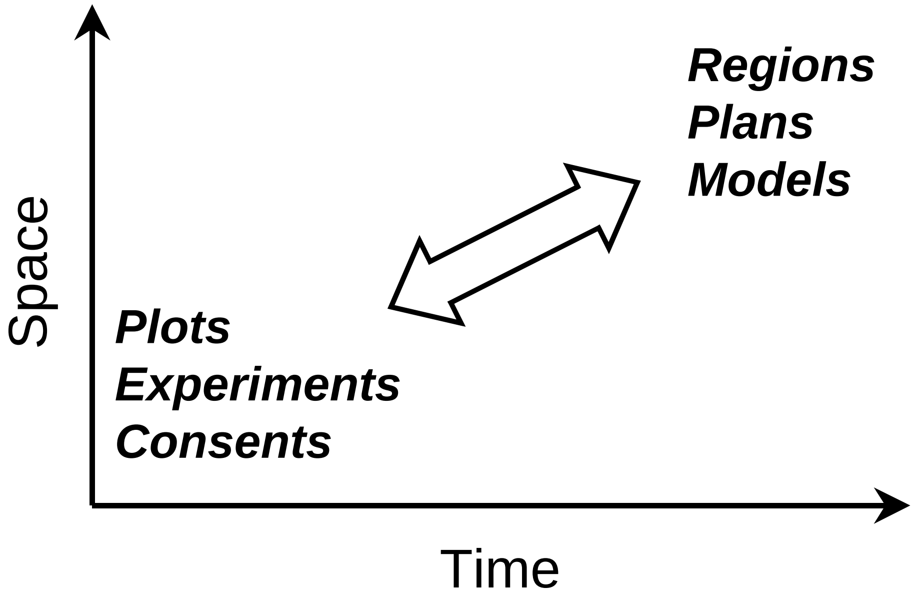

Fig. 3 ICM as a way of thinking