

**ENVIRONMENTAL**  
**REHABILITATION GUIDE**  
FOR SOUTH AFRICA

## ***Praise for Environmental Rehabilitation Guide for South Africa***

This new book by Mike Mentis is a most timely addition to the relatively sparse literature that is available on ways to achieve effective rehabilitation of land that has been disturbed by construction activities of various kinds. Too often in the past we have seen large areas of allegedly ‘rehabilitated’ land that have lost their original land capability and cannot now be successfully returned to effective and productive use. The causes of such problems are poor or inadequate rehabilitation planning, inadequate understanding of the nature and character of land capability, failure to accept that land rehabilitation processes are costly and can – and often do – take many years to achieve effective outcomes, and the ineffective execution of remedial measures.

I am pleased to see that Mike Mentis’ book does not attempt to provide a ‘one size fits all’ detailed guideline or recipe for land rehabilitation. Instead, the book emphasizes the essential need for detailed site-specific planning, understanding the essential principles of soil and land capability peculiar to each geographical location, designing a programme of works that aims to achieve the desired outcomes rather than merely ensuring that particular types of activities have been carried out, and effective follow-up after the remedial works have been completed. Essentially, the focus is on achieving effective and sustainable outcomes rather than merely covering the exposed land with some type of vegetation to improve its appearance.

It has been a privilege and a pleasure to work with Mike Mentis on several large-scale water supply infrastructure projects across South Africa. These provided ideal opportunities for us to discuss and understand the scale and complexity of the rehabilitation problems that characterize construction projects, and highlighted the reasons why many rehabilitation efforts did not achieve their desired outcomes. I am sure that this new book will provide planners, project managers, rehabilitation practitioners, government authorities and academics with a clear overview on how to design rehabilitation and ensure that outcomes are sustainable.

– **Peter J. Ashton PhD**, water quality and water resources specialist

Tried and tested to achieve 100% environmental rehabilitation sign-off across a diverse 550 km pipeline construction servitude, the tools and techniques presented in this book, accompanied by practical yet precise guidelines, help to set and achieve measurable environmental rehabilitation objectives, at various scales. This book is a must-have for all consultants, contractors and students alike wanting to move beyond the 'one size fits all' approach that is so frequently used in environmental rehabilitation, and present clients with workable specifications to reduce environmental risk and get the job done, on time and within budget.

– **Ian Ansell**, former Transnet environmental lead

This book is everything that practitioners such as farmers and those assisting land reform projects have wanted while deliberating how to attend to the severe degradation that our farms and natural resources are suffering. In the past we have had to rely on 'foreign' publications which do not always have practical relevance in South Africa. We also know that no two rehabilitation projects are the same so a simple recipe doesn't always work, but we also know that a sound scientific basis must inform our decisions. This long-awaited book by Mike Mentis will assist us in the critical tasks of saving our natural environment for our children.

– **Roland Henderson**, farmer and land reform practitioner

Section 24 of South Africa's Constitution enshrines environmental rights. The first part guarantees a healthy environment to every person of this beautiful country of ours, while the second part mandates the State to ensure compliance, and prohibits it from infringing on the right to environmental protection. The State is further required to provide protection against any harmful conduct towards the environment.

The *Environmental Rehabilitation Guide for South Africa*, written by Dr Mentis, is a very useful reference for practitioners and environmental regulators in the construction, infrastructure, project, agriculture, and mining fields as a guide to best practice in environmental rehabilitation, to help restore the environment after high-impact activities.

Much of the guidance goes beyond mere legal compliance and offers solutions as to what rehabilitation should achieve, and how to achieve it. This is a must-have reference book for any regulator or practitioner involved in rehabilitation activities in South Africa.

– **Valli Moosa**, former Minister of Environmental Affairs



## ABOUT THIS BOOK

This book is a guide to why environmental rehabilitation is necessary, the standard to which it should be done, and how to do it. The guide is written in the context of South Africa where the Constitution requires health, wellbeing and the environment to be protected. The obligations that the supreme law of the land mandates are technically sound. Natural capital is indispensable, non-substitutable and irreplaceable if damage to environmental function and to the wellbeing of our children are to be avoided. In essence, to rehabilitate is to restore the pre-existing environment. Supposed rehabilitation that does not avoid natural capital loss is not rehabilitation. The logically implied high standard to which all rehabilitation should be done is buttressed by the Constitutional provision for equality before the law. It is easier to comply with principles 100% than 98% of the time, and any exception is on a slippery slope to biospheric ruin. Using the Constitution as the ultimate frame of reference, the guide explains, for any given case, derivation of a rehabilitation objective, its boundary conditions, the interventions to be applied, and deploying simple powerful metrics to measure achievement. The key elements of much rehabilitation – landscaping, runoff control and revegetation – are explained in terms of what the finished rehabilitation product should look like and how to get there. The approach to rehabilitation taken in this book, and the rehabilitation standards and methods explained, are not based on cost-benefit analysis and other financial trading off tools. These tools rely on discounting and pricing of non-market goods, all of which are infinitely debatable. Rather, this book rests on experiential learning as to what is sustainable. Sustainability, while a clichéd word, is here given operational definition. Though this book is focused on rehabilitation in

the humid and semi-arid regions of South Africa, the principles it uses are applicable across environmental management generally and the book is written for business and political leaders, government officials, project managers, rehabilitation practitioners, farmers and civic institutions.

**Mike Mentis PhD**, consultant in business and the environment



## FOREWORD

Construction activity (*eg* infrastructure, mining, agriculture, *etc*) often causes severe, long-term damage to the environment. It can destroy ecosystems and pollute water, soil and air. These impacts have consequences for the health and wellbeing of affected communities. In South Africa, mining regularly encroaches on the country's strategic water source areas. In Mpumalanga, which contains most of the country's high-yield soils, and where coal mining has dramatically reduced the availability and productivity of this land, its impacts have potential implications for the future of our food security. On top of that, there are currently hundreds of abandoned or ownerless mines, the collective rehabilitation costs of which have been estimated at around R100 billion.

It is therefore crucial for companies to mitigate and rehabilitate their negative environmental impacts. This is expensive. But by law, in accordance with the polluter-pays-principle, the company that causes the environmental impacts (and reaps the profits from doing so) must pay these costs. This is not always done. There are many reasons for this, not least of which are the insalubrious human traits of greed, corruption, and selfishness. But added to this is the absence of proper planning and/or lack of knowledge around environmental rehabilitation. So even in cases where significant effort is made to comply with laws requiring sound rehabilitation of sites, one still finds deplorable attempts at putting things back together again. These problems are compounded by the fact that the State's (*eg* Department of Mineral Resources) compliance monitoring and enforcement of rehabilitation obligations is poor. Post-mining rehabilitation is a major issue across the world, but nowhere as important as in South

Africa, *ie* in a resource-rich country that has significant developmental challenges.

Enter Mike Mentis and his book on environmental rehabilitation.

There may be some readers who do not know the author. Mike Mentis has worked as an ecologist for a conservation agency, as a professor in ecology at a university, and as an environmental consultant specialising in environmental rehabilitation. Throughout his career he has remained an avid student of ecological phenomena, the explanations of which mostly elude the naked eye. Thus, his professional foundations are deeply rooted in observation, hypothesis setting, data collection, analysis, interpretation, reflection, and doing – an endless cycle. As a compulsive practitioner who takes pride in his work, he has an insatiable appetite for proving himself wrong. In short, Mike Mentis is a philosopher, thinker, scientist and practitioner. Few ecologists can claim the breadth and depth of perspective and experience that he can. But Mike Mentis has not invited me to praising his virtues in this foreword.

The book sets out with metronomic discipline the requirement that sustainable environmental rehabilitation requires a clear and simply articulated objective, boundary conditions describing the standard to which this must happen, and predesigned measurement of the degree of attainment. In the process, Mike Mentis challenges in equal measure those who ideologically oppose development, and those who believe that economic growth should not be constrained by onerous environmental parameters.

This book is intended, as one would expect from the title, for every environmental consultant who has a professional interest in restoring environmental function and capability. But more than that every land manager, be it in agriculture, forestry or conservation, will want to have a copy of this book at the ready. Perhaps most importantly, this book is also for those who make key decisions about whether mining, or other forms of avoidable environmental impact should in the first instance be allowed, and in the second, whether rehabilitation efforts are done in accordance with the highest law in our land, *viz* our Constitutional obligations.

Mentis dispels the notion that environmental rehabilitation can be done from a recipe book. There simply is too much variation and too many variables associated with each rehabilitation project to produce such recipes. He leads the reader as far as possible, but all the while making sure that it is the reader who asks and answers the right questions.

WWF's interest in rehabilitation lies both at the very early upstream part of the process (*ie* before permissions are granted for potentially environmentally harmful activities), and at the very downstream part (*ie* post-closure). In the early stages when decisions are to be made about mining, construction or other development proposals, it is imperative that the decision-makers who ultimately issue permits, licences, *etc* fully understand the potential long-term burden that such decisions may place on society. If damaging activity cannot be rehabilitated to an acceptable predefined state, then it makes no sense to allow it to proceed. Or alternatively, if such activity can be rehabilitated to an acceptable predefined standard, but is not, then broader society needs to be empowered to ensure that it is done.

My guess is that this book, as with our Constitution, will be read and treasured by good people who want to do the right thing. It may be too daunting for those who blatantly find ways to externalise the consequences of their profit-driven activities – be it financial, health, social and/or aesthetic burdens – onto others.

In this book on rehabilitation, Mike Mentis makes it abundantly clear that it is a Constitutional obligation under South African law for any beneficiary of such potentially environmentally damaging activity to take every precaution possible so as to fully account for, and remediate, the environmental legacy that will be left. Nothing more, BUT unequivocally, nothing less.

**Morné du Plessis**

CEO, WWF South Africa



## PREFACE

When I dreamed up the idea of a book on environmental rehabilitation – the practice of restoring to a former condition – I envisaged something of a collection of recipes. Rehabilitation comprises a wide array of interventions. How to fix a donga. Where and how to build a gabion. How to stabilize an embankment. How to revegetate. And so on. The prospects were that such a book would be tedious to write and dull to read. It took a while to gather momentum – a decade – but along the way I gained experience and insights. I happened also to consider two big questions, ‘should I be doing rehabilitation at all?’ and ‘if so, to what standard?’. These questions, especially the second one, posed serious intellectual and practical challenges, and, in due course, defined the book.

What finding these big questions, and then answering them, did was to transform the content of the book from a dreary compilation of look-up recipes to a more thought-provoking guide on what constitutes rehabilitation and how to develop from principles the detailed end-points and procedures for any particular application. The intent of rehabilitation is to restore damaged environmental structure and function. Any supposed rehabilitation that does not avoid run-down of natural capital is not rehabilitation. The basis of this view is argued in Chapters 1 and 2. This change in approach of the book might disappoint some potential readers and users who want simple executable instructions – add water and stir for five minutes. But, aye, there’s the rub. One thing my experience taught me was that a common reason for poor or failed rehabilitation was that it was done unthinkingly, following a recipe, repeating what was done on a previous project, not delving into and understanding the processes at site, not modifying the generic guide to fit the exact circumstance, all without

a clear idea of exactly what the rehabilitation was to achieve. Of course, hindsight is the exact science, and much of my learning has been at the expense of the mistakes of others. I applaud my teachers, unwitting as some of them were. A lot is to be learnt from failures, and little is gleaned from the successes except when they are compared with the failures. The upshot is that if there is any recipe or technique that needs to be known and applied, it is being clear on what it is that is to be achieved, to what standard, and how success and failure are to be measured. A recipe of sorts that might be, but it does not have the simple executability of ‘add water and stir for five minutes’.

Having now asserted that environmental rehabilitation needs an objective, boundary conditions, and measurement of the degree of attainment, some explanation is warranted. A key notion is that objective, boundary conditions and manner of measurement vary from case to case, and beyond generic definitions as explained in this book and given in the glossary, the specifics are liable to vary from one application to the next.

As ill- or undefined as a rehabilitation objective often is, when pressed on the matter, few would contest that an objective is needed. If an activity does not have a purpose, how might it be decided when the activity is complete? Seemingly the purpose in many a rehabilitation project is often little more than occupying people’s time and earning them an undeserved salary. Unsurprisingly, what rehabilitation might be done under these conditions has shortcomings, and little wonder that clients and contractors, having previously seen precious resources squandered, are reluctant to fund rehabilitation. You get what you pay for, though, and if the budget is only a shoe-string then expect no more than shoddy thinking, planning, implementation and results... talk about a self-fulfilling prophecy!

In the cases where rehabilitation is provided with a purpose, this is commonly written as multiple objectives, often set out as a series of bullet points. Almost invariably, the purported incisiveness is, upon scrutiny, confusing and poorly executable. Just one objective can be difficult enough. Attaining two or more objectives concurrently is mostly improbable if not impossible. Environmental and social scientists are serial offenders, and some of them doggedly try to defend their position. I once had the idea of writing a novel based on a mad anthropologist with whom I worked and who lived in a chaotic world of multiple social goals, and multiple girlfriends. Conflict in Don Juan’s life was inevitable. So it was with me in

writing a novel and this book. At the minimum it is one goal at a time, and I prioritized this book over the novel.

Imagine a soccer game with more than one goal to kick for. It is said that soccer is a gentleman's game played by hooligans, while rugby is a hooligan's game played by gentlemen. Rugby is complicated. There are several ways of scoring points – a try (5 points), conversion (2 points), penalty kick (3 points), drop kick (3 points) and penalty try (7 points). The rules are fiendish. Is soccer's comparative simplicity the reason why it is the world's most popular sport instead of rugby? Soccer players are clever, not hooligans. Get the ball in the goal – with foot, head or penalty. Simple as that. The billions of avid soccer supporters can get their minds around this, even after a few beers. Yet my environmental and social scientist friends, aided and abetted by government authorities, insist on arguing that the real world is more complicated than even rugby. The world is indeed complicated, if you want to make it that way. To paraphrase Ernst Schumacher in his bestseller *Small is Beautiful*, any idiot can make things complicated, but with effort and thought just about anything can be made into Einstein's '...simple, but not too simple'. Environmental and social scientists, and government authorities, play rugby (or something still more complicated) not soccer, at their peril.

Note that in soccer, while the goal is to get the ball in the net, the game operates according to rules that generically can be labelled as constraints or boundary conditions. The ball must stay within a bounded playing field, for instance, kick the ball not the opponent, hands may not be used except by the goalie, and so on. These rules do not form a series of multiple objectives. The objective is to score a goal, and the rules are the conditions or constraints under which scoring a goal is controlled. Without the rules soccer would not be a spectator sport. It would be unintelligible chaos, like rugby and hooligan environmental and social science in which numerous objectives and boundary conditions get confused. I hear my coal mining clients say 'production comes first'. This rightly identifies their purpose – produce coal. But what then? Do safety, health and environment come second, third and fourth? No! Coal is produced subject to safety, health and environmental rules. Entry into the mine premises under the influence of alcohol or drugs is not permitted. Personal protection equipment must be worn on site. An area must be evacuated before blasting. And so on. In this context it is appropriate to conceive of an activity being pursued subject to constraints or boundary conditions.

The intention to ‘put it back as it was’, like ‘kick for a goal’, is a purpose, but by itself is not enough. The objective ‘put it back as it was’, like any other objective, requires qualification. It is improbable that any two spots on earth, or the same spot at different times, are *exactly* the same. There is near an infinity of parameters, and there is Heisenberg’s uncertainty principle which imposes limits on measuring and knowing. To use ‘put it back the same as it was’, as with any other objective, requires the key criteria of ‘the same’ to be specified. The key criteria are not everything, not all conceivable parameters. For purposes of rehabilitation the key criteria are issues such as land capability, environmental function and sustainability, as explained later. The sometimes heard ‘we can’t put it back as it was’ are the ramblings of those who have not applied knowledge and understanding to the problem. Qualifications or boundary conditions to the objective, whatever it is, are needed.

Writing a workable objective with appropriate boundary conditions calls for what Schumacher said, not the casual ramblings of a lazy hooligan, but deliberate and incisive thinking. For any particular situation there possibly are many equally acceptable ways of articulating it all. Whatever the situation, the purpose statement must be pragmatic. For example, I say to my mining clients that undertaking rehabilitation might be articulated as follows.

The objective is to minimize the cost of putting it back like it was subject to the following boundary conditions.

- Restored land capability not less than  $p$
- Landscape form exceeds  $q$
- Soil loss does not exceed  $r$
- Soil fertility exceeds  $s$
- Species composition exceeds  $t$
- Pasture structure exceeds  $u$
- Pasture vigour exceeds  $v$

where  $p$ ,  $q$ ,  $r$ ,  $s$ ,  $t$ ,  $u$  and  $v$  are specifications defined by an exact computer algorithm. For example, if the land capability to be restored is ‘arable’, then the computer algorithm specifies the conditions of soil depth, land slope, *etc* that must be met for the rehabilitation to be within the boundary condition ‘arable land capability’. Enter the site data into the computer and the algorithm consistently outputs an objective result – this meets, or does not meet, the land capability requirement.

There are possibly many ways of conceiving a workable rehabilitation objective with boundary conditions. However, it is worth emphasizing key points of this particular rendition.

There is only one objective function. Maximizing, minimizing or optimizing two or more objective functions simultaneously is improbable. So, the frequently blurted ‘minimize negative impacts and maximize positive impacts’ and other such inanities are avoided.

Minimizing the cost is an objective to which clients and project managers are favourably disposed. No one wants to spend more money than necessary to get the job done. The specifications of getting the job done – to a high standard as explained in this book – are spelled out exactly. The specifications bound or define what is the acceptable rehabilitation product. What money is not wasted on rehabilitation in this project is available for good rehabilitation on the next project.

Meeting specifications can be of the pass or fail type, or graded to index degree of conformance. This aids in identifying where failures or weaknesses lie, and is a key step in knowing what to fix and then working out how to fix it. That is consistent with continuous improvement and the error elimination theory of growing knowledge.

The specifications are partly a knowledge-base. They are accumulated experience. They are amenable to ongoing research, revision, improvement and, importantly, adaptation to varying circumstances. The approach can be tailored to fit any of a variety of applications. The specifications are also partly a function of appetite for risk, a notion explained in this book, indexing how accepting or averse an organization is to attaining a particular level of performance. For example, the mining industry is averse to any rehabilitation standards, methods and products that might cause injury or death. A benign rehabilitated landscape is demanded. Yet, by comparison, in hang-gliding and mountaineering the sport participants are much more accepting of a high chance of misadventure, and the environment is far from benign. This perspective deals a crushing blow for any hope that one precise definition for rehabilitation can specify on all applications. It is possible to have a generic definition for rehabilitation – restore to a former condition – that applies universally, but exactly what rehabilitation is or is not is liable to vary from one case to another.

The objective function and its boundary conditions do not cover everything about environmental rehabilitation. Government authorities and activists are champion at wailing that the picture is incomplete. Yet,

in the extreme, and by extension of Heisenberg's uncertainty principle, it is not possible to know 'everything'. More pragmatically and quite as important, resources of budget, manpower and time are finite. If the objective function and constraints are made 'comprehensive' (how the folk that Schumacher scolds love this term) it is likely that the scheme will be complicated (hooligan rugby not gentleman soccer), demanding on resources and therefore costly to implement, and liable not to be continued or even put into effect at all. Partial knowledge is better than no knowledge. Partial knowledge, focused on key performance indicators, is better still. There is burning need for simple powerful metrics.

The metrics are more than just measurement in environmental and social sciences. They are necessary tools for project management. How can stakeholders be convinced that a proper rehabilitation job has been done when there are no easily measurable standards agreed on up front, and performance against the standards not actually measured and reported upon? Should a contractor be paid for spreading fertilizer and grass seed, or for raising soil fertility to meet requirements and to establish a vegetation cover that conforms to specification? Mostly it is not the contractors who are to blame for focus on action instead of performance, but rather the client and his project manager (and the environmental and social advisors) who lapse in accountability... eight-to-five workers receiving the undeserved salary.

The first limitation of this guide has now been covered. This is not a look-up cookbook that offers instant solutions. It urges devising objectives, boundary conditions and metrics to fit the exact circumstance. Of course, many a project faces tight timelines and, in the rush to get started, the powers-that-be do not have time for what they call nice-to-have but non-essential. Yet resources wasted in the beginning on these supposed luxuries are liable to be more than saved in the end, and, in my experience and depending on the project, the slippages can run to decades and hundreds of millions of rand.

Consider further limitations to this book.

This is not a legal compliance guide. Beyond using the Constitution as the ultimate frame of reference, this book is not about what the law says. Rather, the guide explains what rehabilitation should achieve, and how to achieve it. The explanations are intended to guide the authorities who write rehabilitation regulations as much as to help managers of rehabilitation. Hence, if the rehabilitation managers follow the prescriptions in this guide

they might, or might not, comply with existing laws. My bet, though, is that most instances of supposed rehabilitation perhaps comply with the law, but fall short of good rehabilitation practice. In general, both rehabilitation practice and rehabilitation regulation are defective. If that were not so there would be no need for this book.

This book is also not an engineering guide. Yes, rehabilitation might involve engineering, and other technology, but they are only means to an end. What is the end? How is the end decided? How is the end to be measured? This guide tries to explain how ends are derived, what the objectives and boundary conditions are, what the key requirements are in the process of attainment, and how to measure getting to the end point. Given all this, engineering, economics, science and technology can and should be used to help achieve the objective.

This might jar with many engineers, scientists and technologists who claim that their practice is professional. They say that what they do is based not on fantasy but on calculations, data, measurements and technology. This is not entirely wrong. Hopefully, they are indeed using facts. What they are doing should never be inconsistent with the facts, but ultimately it is not, or should not, be driven by the facts where the facts of any individual case are positive issues about how the world is. For example, action A leads to consequence B, such as stripping off the protective plant cover leads to erosion. That is how the world is. Whether erosion is wanted, or to be avoided and prevented, or to what extent it should be avoided and prevented, is a normative issue about how the world should be. The choice between, on the one hand, enjoying short-term benefits at the cost of erosion and land degradation and, on the other hand, foregoing short-term benefits to avoid future losses is a matter of human values rather than facts. To be sure, facts can and should be used to inform us on consequences, but the identities of good and bad depend on what we like and want, or dislike and do not want. Preferences can be expressed factually (*eg* 20% likes and 80% dislikes) but the causes of the different preferences may be as elusive as why I like blondes.

Objectives are not independent of their means, and costs, of attainment. Objectives are indeed constrained by means, but to an extent only. There once was the expression ‘we can do that no more than fly to the moon’. Now that man has flown to the moon, we are aware that many, though not all, things are indeed possible. While there are fatal flaws to some projects, engineers are clever and can usually design a solution. It is often

not the inventive flare that is missing, but that the timing and sequence are wrong. Take, for example, the scour valves on a water pipeline. The pipeline is planned, the location of scour points identified, and scour valve chamber and protection of the discharge area designed. At inspection upon completion of construction, it is observed that the stone-pitching to dissipate the energy of scour flow faces uphill, it has a concave shape that concentrates discharge instead of a convexity to disperse flow, it is laid on top of the soil surface instead of dug into it, and so on. The shortcomings could have been avoided had the boundary conditions to scour point design and function been thought through in the beginning. And correcting the mistakes after construction is not a proposition because the contractor followed the design he was given, there is no budget to fix it, the design team will defend the correctness of its design lest it be held liable for any fixing cost, and the outcome is, as my colleague Sabelo Mkhwanazi quips, *umsebenzi wenkawu* (the job of a monkey).

For most projects the objectives and boundary conditions are not challenging to meet. The ends are not constrained by the means. Yet the ends are often not properly met. While the pipeline might deliver the specified volume of water, or the road might carry the requisite traffic, there is undue cost to people and the environment. The fit-for-purpose has shortcomings. Any scrutiny of the works reveals that project mitigation, including rehabilitation, is less than 50%, whatever the uncritical and superficial tick-box audit of the environmental control officer might say. These maladies are mostly a symptom, not of an unattainable objective, but of failure to clarify up front the objective with boundary conditions, to put it up as the guiding star, to define the means of navigation, and then to control to ensure the design is conformed to.

Most of the content of this book is not based on controlled experimentation any more than the abilities of the maestro musician. There is no long list of authorities to substantiate the present work, statement by statement. Rather, the book relies on the 10 000 hours syndrome. It is said that to be accomplished or expert at anything, 10 000 hours of engaged practice is required. My learning was experiential rather than by experiment. The raw material is to the order of 10 000 plot-years. Not much different from controlled experimental science, I guessed at what was important, devised metrics and tested extensively. Superficially this might not seem to have the rigour of the controlled experiment. But the supposed rigour of controlled experiment is traded off against 'degrees of freedom'

of the bigger enquiry. The metrics, if invented correctly, can be applied quickly anywhere anytime at little expense – at the roadside, while hiking in the mountains, when on holiday in Australia. The quicker and cheaper the data can be amassed, the more data there is for hypothesis-testing, and the faster can knowledge advance. Take grass cover as an example. From the outset it looked a useful parameter – it protects soil against erosion, its abundance indexes revegetation success, it helps replenish soil organic matter, and it is of utilitarian value to the livestock farmer. I dreamed up a quick way of measuring grass cover. Stride across the sample area and every time the right foot strikes ground, rate the live perennial grass in front of the foot – 5 (lawn), 4 (nearly lawn), 3 (more grass than bare ground), 2 (more bare ground than grass) and 1 (sparse to bare). Done this way, many sites and thousands of points can be observed in one day. Crude as this may be, the ‘big data’ quickly permit a relational knowledge. For instance, ‘good’ humid grassveld has a cover rating of 3 or more. And, if after a year the cover rating of the grass establishment is less than 2, then plough it up and start afresh, otherwise a cover less than required can be improved by pasture reinforcement – boost the soil fertility to meet specification *s* and defoliate as soon as the grass matures. Testing and refining the relational knowledge are ongoing.

Though my experiential learning is not written up in formal articles published in refereed journals, it is quite as testable as controlled experiments. I say it is scientific because it is amenable to being tested and vulnerable to being overthrown at any moment. In fact, it has had many moments of testing. I test it every time I undertake a rehabilitation assessment. I venture that, by comparison, many controlled agricultural and ecological experiments, and exquisitely executed field studies, published in the most reputable journals, potentially repeatable as they might be, are never repeated.

In saying how the content of this book was derived I am explaining not defending. I am happy for the content and my experiential learnings to be challenged, found wanting and improved.

Inevitably any technical book contains jargon. A glossary is included. Readers are encouraged to use the internet to explore terms and concepts.

In writing this book I am very aware of the limitations of my knowledge. For example, I am not an engineer, yet much environmental rehabilitation benefits from engineering expertise. An important limitation of this guide is therefore that I have focused on things of which I have first-hand

experience. Yet even here I beg that the reader not unquestioningly accept my point of view. Hopefully my guide can prompt users to devise and execute a plan appropriate to their circumstances.

The book is also bounded by a temporal and spatial context. Tomorrow the mindset might be different. Hopefully it might steer away from the self-destruction that Aldo Leopold, Stephen Hawking and others argue. Maybe this guide can help, at least in some small way, in ‘recalculating route’ as my TomTom says when I take a wrong turn. Maybe we can come to see ourselves not as exploitative owners of a commodity-biosphere but as components of the biosphere and dependent on it. Technology is a bad master but a good servant, and maybe we can re-orientate from technology-driven to value-driven where the values are not profit but resilience and sustainability. If these maybes come about, this book will lose the ring that it now purports to have.

I have also focused this book on the humid and semi-arid regions of South Africa. This is where I have spent a lifetime. Given different location, geology, climate, soils, biota, customs, laws and people the right thing to do might be different to what I propose. I like to think though, whatever you do, a value-driven objective with clearly defined boundary conditions and specified metrics is going to help you.

If anything in this book has merit, there are many people and institutions that must take credit. Teachers, mentors, students, colleagues, employers, clients, journal editors, anonymous referees, friends and foes helped with instruction, advice, criticism, sometimes plain obstructionism, provision of opportunities, and sharing of knowledge, know-how and insights. I hesitate to mention any institutions and people because I cannot list them all. The institutions that gave me extended opportunity included Natal Parks Board, University of Natal, University of the Witwatersrand, Richards Bay Minerals, Ingwe/BHPBilliton/South32 (how the leopard hath changed its spots), Lesotho Highlands Water Commission, Lesotho Highlands Development Authority, Sasol, Transnet, Trans Caledon Tunnel Authority, and Glencore. People, some retired or deceased, who most have shared knowledge, imparted skills, inculcated values, argued and debated, and trusted me with opportunity include Rudi Bigalke, Roger Collinson, Barry Clements, Digby Wells, Brian Cook, John Ledger, Bob Hitchcock, Mark Wood, Mark Berry, Chris Naudé, Ntaoleng Mochaba, Werner Beukes, Roland Henderson, Kubashni Mari, Ryan Macnamara and Tim Liversage. I am grateful to Dave Rowe-Rowe, Pete Ashton, Millicent

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I am indebted to my wife Lesley. While I absented myself in the boon-docks, stuck my nose in a book, glued myself to a computer, day-dreamed or prattled away on some arcane and abstruse topic she observed critically, compensated for my only intermittent attention to home affairs, and got on with the onerous and responsible tasks of holding the household together, raising Colleen, Glenda and Ella, and delivering sumptuous and nutritious meals. Genes are powerful things, but the environment makes for a lot – the *sine qua non* in this case. Some guys are undeservedly lucky. Thank you, Lesley, Colleen, Glenda and Ella.

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