Operations Research Society of South Africa

At the Forefront of Analytics in Africa

ORSSA Newsletter June 2016

www.orssa.org.za

45th ORSSA Annual Conference

11–14 September 2016

An advanced warm welcome to the 45th Annual Conference of the *Operations Research Society of South Africa* (ORSSA). The conference will be hosted by the Western Cape Chapter of ORSSA, and held at Lanzerac Wine Estate in Stellenbosch from 11-14 September 2016.

The conference will open with an optional tutorial on agent-based simulation by Brian van Vuuren on Sunday afternoon September 11th and a welcome reception on the Sunday evening, and will close at lunchtime on Wednesday, September 14th. Participation over the full spectrum of Operations Research is encouraged, including papers of a more fundamental nature, those on the application of Operations Research techniques in business and industry, about topical issues in Operations Research, and about the philosophy, teaching and marketing of Operations Research.

The conference keynote speakers will be Erwin Pesch and Paul Fatti. Unfortunately, due to unforeseen circumstances, Elena Fernandez had to withdraw her participation in the 2016 Conference.

Following the successful introduction of published conference proceedings in 2011, authors will again have the choice of either (a) only presenting papers orally at the conference, or (b) submitting full papers (which will also be presented orally at the conference) for inclusion in the peer-reviewed conference proceedings. Registration, and submissions of abstracts and full papers opened already on the **14th of March 2016.**

Delegates are responsible for their own travel and accommodation arrangements. Lanzerac Wine Estate is recommended, as the Society has arranged competitive rates for delegates at the venue.

Lanzerac Wine Estate – http://www.lanzerac.co.za/

Erwin Pesch
(opening keynote)

Paul Fatti
(closing keynote)

Brian van Vuuren
(tutorial)

Lanzerac Manor House

Important Dates

14 March 2016	Early bird registration & abstract/paper submission opens
11 April 2016	Abstract submission closes for reviewed papers
18 April 2016	Notification of acceptance of abstracts of reviewed papers and go-ahead to submit full papers for peer-review
23 May 2016	Submission of full papers for inclusion in the conference proceedings closes
15 July 2016	Abstract submission closes for oral presentation of all papers
23 July 2016	Notification of acceptance of reviewed papers for proceedings
24 July 2016	Notification of abstract acceptance for non-reviewed papers
29 July 2016	Early bird registration closes
14 August 2016	Cut-off for qualification of reduced room rates at the hotel
21 August 2016	Registration closes

Please visit the ORSSA website and click on the link *ORSSA 2016* for more information:

www.orssa.org.za

From The Editor

By Bernie Lindner (berndtlindner@gmail.com)
& Brian van Vuuren (brianvv@sun.ac.za)

Bernie Lindner

Brian van Vuuren

Just like that – you blink, and we are half way through the year. And with that, the second ORSSA newsletter of 2016 is here. This quarter's newsletter focuses on something we should all be taking seriously – the way the environment around us is changing and what we can do to help preserve it.

Last year ranked as the 96th worst year out of the last 100 in the agricultural industry. And 2016 hasn't been much better. If you live here in the Western Cape, you'll know that this Summer was particularly uncomfortable and, on top of that, we are yet to receive decent rain for the Winter.

It's clear to see how the environment is being affected by human activity, with agriculture and livestock farming feeling the harshest effects. Water restrictions across the country and soaring food prices are only going to get worse and it's time to think smart about how we can tackle these challenges. In this edition, we take a look at some projects with ecological applications, both in the farming and agricultural industries.

Also of importance to note is that our annual conference is just around the corner. You can find all the details you need in the newsletter – don't miss out! Lanzerac hotel promises not to disappoint.

I would like to thank Brian van Vuuren for helping me with this edition.

Until September in Stellenbosch,

Bernie Lindner

Features Page

SOCIAL MEDIA

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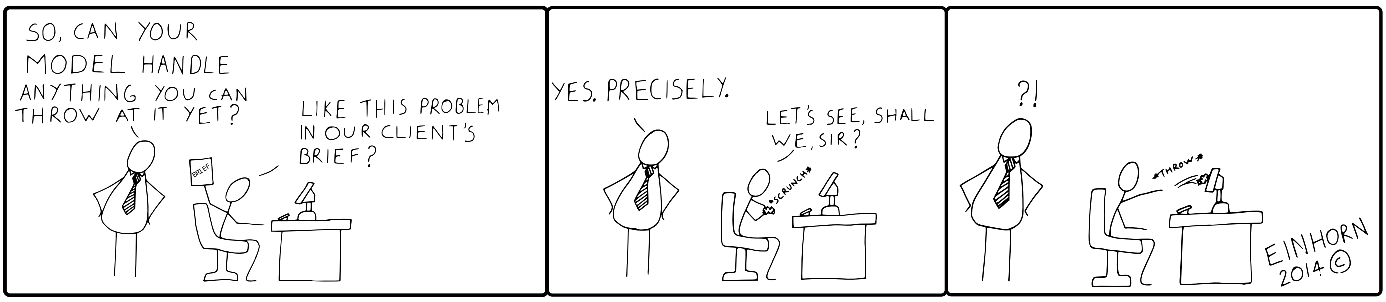
QUERIES & CONTRIBUTIONS

Any queries or contributions to the Newsletter are most welcome, especially article submissions. For any queries or contributions, please contact the Newsletter editor at *berndtlindner@gmail.com*.



One from the archives - June 2014

From The President's Desk

By Winnie Pelser (wpelser@csir.com)
ORSSA President


Winnie Pelser

The June edition of our Newsletter indicates the fact that the second half of 2016 is upon us! This is the last edition of the newsletter before we meet for the 45th Annual Conference. The conference will take place at Lanzerac in Stellenbosch from 11 – 14 September 2016. Preparations for the conference are underway. The Local Organising Committee (LOC) is led by Danie Lötter. Details of the conference can be found on the ORSSA webpage (www.orssa.org.za).

The LOC has secured a number of sponsors for the conference. I would like to thank both the LOC for their efforts and the sponsors who have agreed to support the conference. Sponsors so far include the Department of Logistics at Stellenbosch University, the Department of Industrial Engineering at Stellenbosch University, the Department of Decision Sciences at the University of South Africa (UNISA), Blue Stallion, OPSI Systems, Gurobi, Pivot Sciences and the North-West University (Centre for BMI).

The conference keynote speakers this year will be Professor Erwin Pesch from the Management Information Sciences at the University of Siegen, Germany and Professor Paul Fatti. Professor Pesch's research areas are in Logistics, Management Information and Decision Support Systems, Project Management and Scheduling. Paul Fatti is an emeritus Professor and Honorary Research Professor at the School of Statistics and Actuarial Science and the Dental Research Institute of the University of the Witwatersrand. He has been a valued member of ORSSA for many years. Delegates are invited to an optional tutorial on 11 September. The tutorial presenter will be Brian van Vuuren from the Department of Industrial Engineering at the Stellenbosch University. More detail on the speakers can be found on the ORSSA 2016 Conference website under Keynote Speakers. Registration for the conference is open and interested people are encouraged to register and organise their accommodation as soon as possible. Early bird registration closes on 29 July 2016. Submission of abstracts for papers closes on 15 July 2016.

The different chapters are active, and regular meetings are held. I would like to thank the chapter chairs, chapter committees and all members who organise and attend the chapter events. The Meetup groups are continuing and members are encouraged to support these meetings. Meetings are regularly held in the Johannesburg, Pretoria, Vaal Triangle and Western Cape chapters.

Invoices for membership fees payable were sent out with the March Newsletter and I would like to encourage all members to settle their accounts. In some instances payments are overdue and I would like to request your assistance with these payments to help ensure that the Society can continue delivering a high-quality service to its members. Enquiries about the invoices or any other financial related matters can be directed to Dave Evans who is both treasurer and Database Manager. His contact detail is available on the website.

In conclusion, I want to thank everyone for their contributions to keep our Society at the forefront. Thank you to every member of the Executive Committee for managing his or her portfolio in a professional way amidst severe working pressures. As always, please feel free to contact me, or any member of the Executive Committee should you have any request or ideas that could help us to improve the Society's service to its members.

Enjoy the articles on ecological/biological modelling in this issue of the Newsletter.

With best wishes until we meet in Stellenbosch / Alles van die beste tot weersiens!

Winnie Pelser

Operations Research or World Peace

*by Linke Potgieter, Stellenbosch University, **Department of Logistics** (lpotgieter@sun.ac.za)*


Linke Potgieter

Paul Hawken, an environmentalist from California, USA, once made the comment that sustainability, ensuring the future of life on Earth, is an infinite game, an endless expression of generosity on behalf of all. He went further and stated that we assume that everything is becoming more efficient, and in an immediate sense that's true; our lives are better in many ways. But that improvement has been gained through a massively inefficient use of natural resources. In the same vein, Theodore Roosevelt was quoted saying "To waste, to destroy our natural resources, to skin and exhaust the land instead of using it so as to increase its usefulness, will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them amplified and developed."

It is with these same sentiments that a research group was established by Linke Potgieter at the Department of Logistics, Stellenbosch University, which focusses on issues relating to the sustainable, environmentally friendly and cost-effective management of natural resources. Operations research (OR) has, in fact, over the last few decades, become increasingly prevalent in the natural resources sector, and more specifically, in agriculture, fisheries, forestry, mining and water resources. Even though these systems are usually viewed as separate fields of study, similar research questions are shared between them. In fact, all of them share the common problem of allocating scarcity along time in an optimal manner, or to put it differently, to obtain an efficient use of the resource along its planning horizon. The scale of time or length of the planning horizon is of course very different — an almost continuous renewal in the case of fisheries, periodic cycles in the case of agriculture and forestry (ranging from months to decades), and enormous periods of time in the case of mining resources. Another clear link between them is in understanding the interaction between the use of the resource, and the environmental impact caused by its cultivation, extraction or harvest. OR has played an important role in the analysis and decision making related to these natural resources by helping people understand the complex functioning of the systems and how to manage these systems in an efficient way. Models developed within the context of natural resources may be categorised within almost all of the major methodologies prevalent in the OR literature, although differences within the five areas exist. For example, multi-criteria decision making plays a role in all five areas, but models applied to mining seldom incorporates this methodology. Similarly, many models consider the environment, though these again are not common in mining. Behavioural models are frequently found in agriculture and fisheries to account for the behaviour of farmers and fishermen, while models applied in the forest and mining industry more frequently consider stand-alone enterprises without regard for interactions between different owners [9].

The main methodologies utilised (although not restricted to) by our research group include ordinary and partial differential equations, statistics, metaheuristics, cellular automata and agent-based simulation. These are all used to describe mathematically the real-life systems being modelled, optimise and ultimately help answer some important management decisions without having to conduct costly in-field experimentation.

The research started with a PhD entitled *A mathematical model for the control of Eldana saccharina Walker using the sterile insect technique* [1, 2, 3, 4], which expanded into three Masters research projects, including Brian van Vuuren's thesis entitled *An agent-based simulation approach to model the population dynamics of Eldana saccharina Walker* [6, 7, 8], Pieter de Wet's thesis entitled *A cellular automaton for improving sugarcane agricultural landscape structures*, and DJ Human's thesis entitled *Refugia planning for a Bt-sugarcane scenario*. The underlying theme of all these projects is the development of mathematical and simulation models which may help in improving integrated pest management (IPM) against Eldana *saccharina Walker* in sugarcane in a sustainable and cost-effective manner. Pest management using traditional approaches with pesticides can often be effective, but impose significant economic and environmental costs. In recent years, there has been a global move to research and establish environmentally friendly farming practices, which include land, habitat and pest management. As a result, a number of IPM programmes in a variety of agricultural ecosystems have been developed which combine biological control of pest species, varietal resistance, appropriate farming practices and minimise the use of chemical pesticides. The socio-economic benefits of IPM have been shown to stretch far beyond the financial value of the yield increases achieved. It includes dramatic improvements to human and animal health, and to the environment. Although a number of IPM programmes have been semi-established in South Africa across different agricultural crops, a number of important and newly researched strategies have not yet been included as part of the decision-making. Also, some of the more eco-friendly strategies can be quite costly, and using these strategies should be well thought through in order to be applied cost-effectively. Improving on the current programmes would be a timely and costly approach if only in-field experimentation were to be used in testing different management strategies. Mathematical and simulation models have proven to be of great help in establishing a basic understanding of the systems studied and the possible causes and effects of different management strategies on the population dynamics of the pest species without having to conduct real-life experiments. As a result, in-field experimentation may be done in a smarter, more targeted manner. The models can be adjusted to suit other contexts as well. Contributions are therefore also made in terms of ideas on how to model IPM scenarios in other agri-ecosystems and in understanding the complexities involved in modelling integrated systems.

Within the context of water resources, two research projects are currently conducted, including Heléne van Schalkwyk's Masters thesis entitled *A spatio-temporal model for investigating biological control strategies for water hyacinth* [5], and Noé Caréme's PhD project entitled *A hydro-economic model for water resources management in the Lake Chad region* with the objective of finding an optimal allocation of water resources among the various users in the region.

Perhaps we also share the sentiment of Wangari Muta

Maathai, a Kenyan environmental and political activist and Nobel Peace Prize winner, who stated "Sustainable management of our natural resources will promote peace", because, you know, of course we would all like to contribute to world peace. Not that managing a little moth creature itself would help in the quest for world peace (perhaps more sugar would make people feel more happy, and more water would help in producing more sugar?), but our livelihood is intimately tied to the food we eat, the water we drink and the environments we recreate. With our research we would like to contribute to and promote responsible decision-making when it comes to our natural resources — at least a small drop in the ocean of factors which will result in enhancing in the days of our children an amplified and developed prosperity handed down to them, and less reason for conflict.

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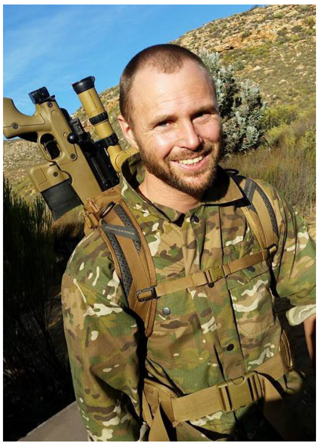
What o(u)r Members are up to

Andries Heyns recently graduated with a PhD in operations research from the Stellenbosch Unit for Operations Research in Engineering (SUnORE), which is based within the Department of Industrial Engineering at Stellenboach University. His research focused on the optimal placement of facilities according to terrain and environmental factors. During the widespread veld fires which ravaged Stellenbosch and other parts of the Western Cape this past Summer, Andries also served as a fire fighter with the Volunteer Wildfire Services, igniting (excuse the pun) his passion for volunteer work and, at the same time, enlightening (see what I did there) him with a better idea of how he hopes to apply his research and experience in the greater world.

Andries has since begun a journey to combine his background in electronics, military decision making and geographic facility location optimisation backgrounds (as well as his passion for conservation) in the design of surveillance and early detection networks to aid in conservation efforts against rhino and other poaching.

Since graduating, Andries has completed a course in combat tracking and anti-poaching which concluded on 3 June. Thereafter, he will undergo fire fighter refresher training whilst writing and submitting a paper related to his PhD work. At the end of June, he will travel to Stockholm and Brussels in order to undergo further training, this time with 'Doctors without borders'.



Andries Heyns

Having the ability to speak a 3rd language fluently also allows him to work in French speaking countries. In fact, he will be going to Bangui, in the Central African Republic, for 6 months from July - January as a hospital logistics manager for 'Doctors without borders'.

As if all of this isn't enough, Andries has also been accepted in a post-doctoral fellowship post at the University of Pretoria which he will begin in 2017, as part of the electronic warfare group, with plans to continue research into anti-poaching, as well as work on the ground – much to his delight.

https://twitter.com/rangerandries

A Spatio-Temporal Model for Water Hyacinth Biological Control Strategies

by Heléne van Schalkwyk, Stellenbosch University, Department of Logistics
Supervisor: Dr Linke Potgieter | Co-supervisor: Prof Cang Hui


Heléne van Schalkwyk

The Amazonian water hyacinth, Eichhornia crassipes, is regarded as the worst aquatic weed worldwide. South Africa is no exception to this. Water hyacinth forms dense impenetrable mats across the surfaces of still or slow-moving water bodies, resulting in high water loss rates and other severe consequences for man and animal. One of the more successful methods of controlling this weed is biological control. Candidate natural enemies are released in infested areas where they attack the weed by feeding on it, thereby contributing to the suppression of the plant population. *Biological control agents* (BCAs) that have been cleared from quarantine can either be released directly once off (classical biological control) or be taken to a mass rearing facility where they are reared in large numbers before they are released, making more frequent releases possible in order to speed up biological control. The popular Neochetina eichhorniae weevil species is considered as BCA in this article.

The sound and cost-effective management of the water hyacinth weed remains a challenge in South Africa. In a study by the author, mathematical modelling is used to investigate the efficiency of different BCA release strategies for different temperatures. A reaction-diffusion model for a temporally variable and spatially heterogeneous environment, consisting of a system of coupled delay partial differential equations, is developed to describe mathematically the population growth and dispersal of water hyacinth and the interacting populations of the various life stages of the N. eichhorniae weevil as BCA on an isolated and bounded two-dimensional spatial domain. The output of the model is translated by a cost function to reflect the cost of water loss for a specific release strategy. The spatio-temporal model may be used to provide guidance towards the optimal magnitude, frequency, timing and distribution of BCA releases, as well as the most cost-effective release strategies.

Equations governing the change in density of the young larval, old larval and adult stages are considered sufficient to model the weevil population [5]. This stage-structured approach makes possible the explicit modelling of the damage caused by old larvae, the density-dependent mortality in the young larval stage and the dispersal of the mobile stages of the weevil population. Time delays are used to account for the time it takes to develop from one stage in the weevil's life cycle to the next [4].

Difficulties exist when modelling ecological systems involving both time delay and diffusion. Since mobile individuals have not been at the same point in space at previous times, diffusion and time delays are not independent of each other. The modelling approach entails more than simply the addition of diffusion terms to the correspondingly delayed ordinary differential equation model. Spatial averaging has to be done to account for the movement of individuals during the period of entering the system and maturing to the next stage. The spatial averaging for a bounded spatial domain, where individuals may additionally interact with the boundaries of the domain, is slightly more difficult to model. Furthermore, the prevailing literature only illustrates the modelling approach for the bounded one-dimensional case. The bounded two-dimensional case is even more difficult to model since explicit expressions for the spatial averaging function do not always exist in higher dimensions [1, 2, 3].

The system of coupled delay partial differential equations in a bounded two-dimensional spatial domain is solved in MATLAB using the partial differential equation toolbox and its built-in functions. There proved to be quite a few difficulties with this implementation. The built-in parabolic function produces the solution to the Finite Element Method formulation of the problem. Since the built-in functions do not allow for time lags, history matrices containing the solutions to the system at all previous time increments are constructed in order to be able to determine the partial derivative of a function where the solution at a certain time depends on the values of the function at previous times. Spatial averaging is performed manually to account for the effect of each reflecting boundary on the averaging process in two dimensions. Implementing frequent releases for the spatially heterogeneous environment proved to be more challenging than for the mean field case. Releases cannot occur at constant points in the spatial domain as after a period of time, the plant may not exist at those points anymore. An algorithm was constructed to search for the closest point to the original point of release where there exist sufficient plant densities for weevil releases.

Example plots of the initial and final population densities after one month for once-off releases of 200 adult weevils at time 0 at singular points on the four edges of a 10m by 10m water hyacinth infested area at a temperature of 30°C are given in Figure 1.

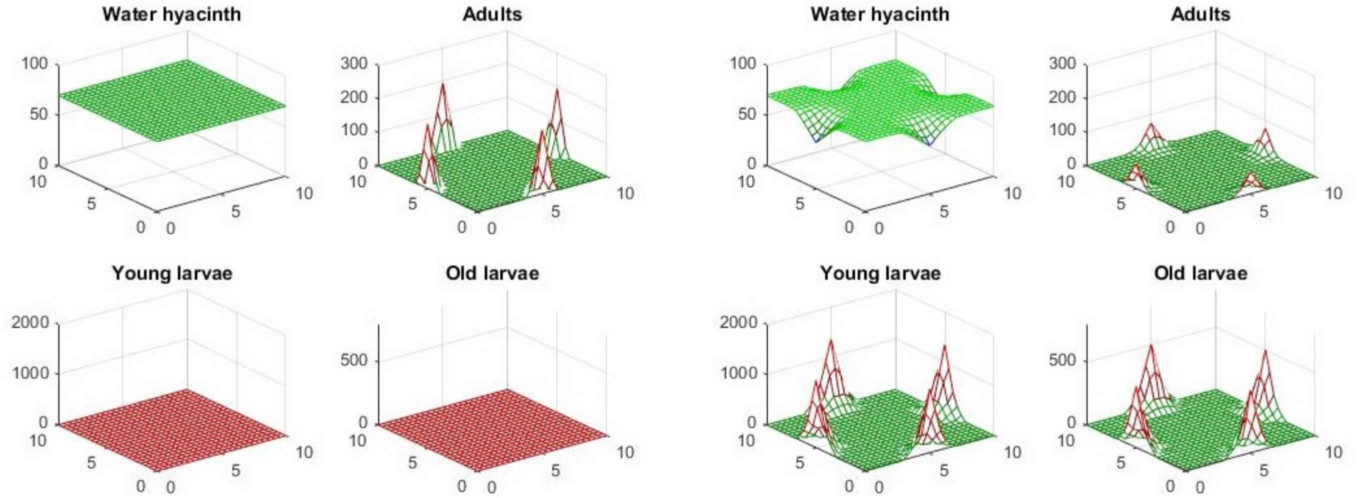


Figure 1: Initial and final population densities for a water hyacinth and weevil system after one month.

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Developing and Sharing Communicating Regenerative Farm Concepts using Simulation

by Henk Roodt, Waikato Institute of Technology (Henk.Roodt@wintec.ac.nz) & Clemens Dempers, Blue Stallion Technologies (dempers@bluestallion.co.za)

Henk Roodt

Clemens Dempers

Economies of scale farming practices derive a commercial advantage from specialisation. It is now clear that this comes at a cost to society and the environment, with small individual farm operations not being able to compete in a global market place and rural communities being ravaged by the effects of urbanization. Hess and Du Plessis [1] refer to the work of John Tillman Lyle, who introduced the concept of regenerative design, and points out that a system that incorporates the natural services of energy conversion, water treatment, waste management and nutrient cycling may contribute to a more sustainable environment.

In this short article we report on work done in New Zealand to show how modeling and simulation can be used to explain how the regenerative concept translates to a farming community, and what approaches and technologies can be utilized to achieve a more sustainable and economically viable alternative to current dairy farming practice.

Overview of the model development

A farmer and an investor approached the Waikato Institute of Technology (Wintec) in Hamilton, New Zealand, to help investigate the concept of a "closed loop", or "low carbon footprint dairy farm". This requirement was unpacked by the modeling team using Concept Maps (Figure 1) during an analysis phase and using IDEF0 principles for the synthesis of a functionally consistent operational model .

The design of the model was done as a process of transdisciplinary co-creation with the investor, the farmer, Wintec agricultural and dairy experts and the Wintec and Blue Stallion modelling team [2]. The agreed upon functional diagram model is depicted in Figure 2.

Model details

The model was developed using the System Dynamics library in the Anylogic Simulation Modeling software product. This allowed us to model the interdependencies of the various components in the system easily, and kept the door open for future development using agent-based models and other process logic.

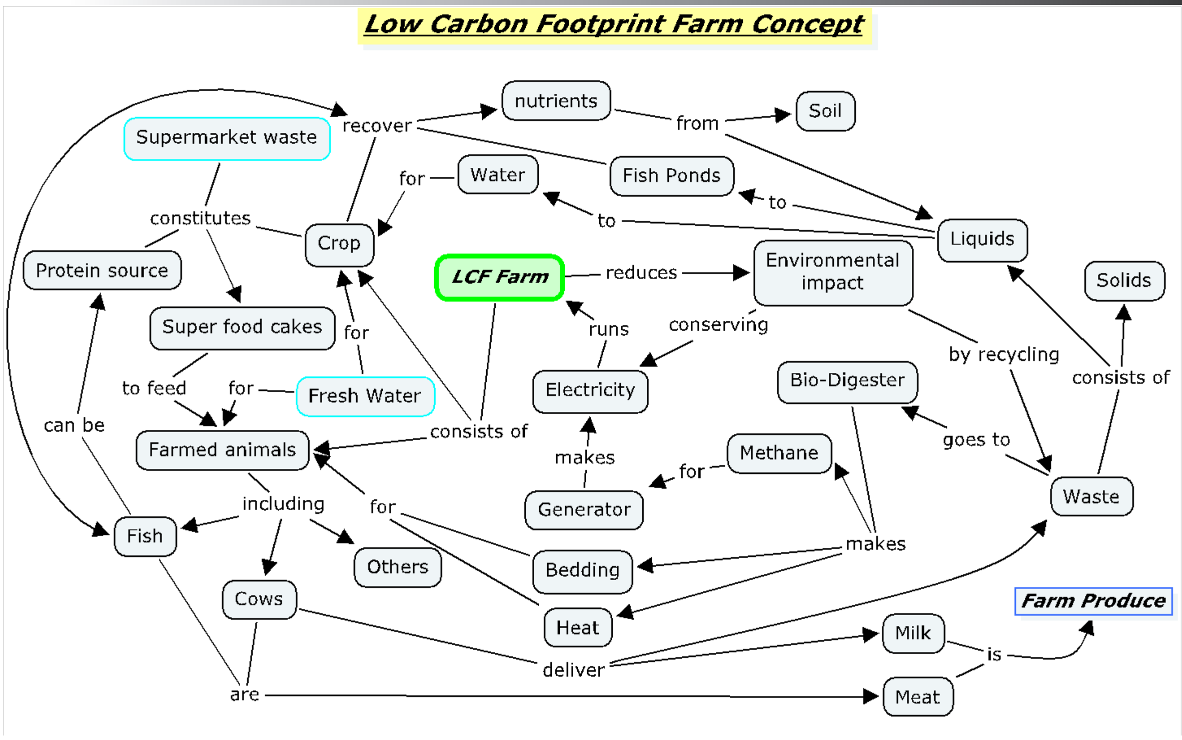

Figure 1: Concept Map of Low Carbon Footprint (C) 2014 TS Farming Solutions.

Milk production

The key component of the model is the cow — as inputs it needs water and feed (nutrients with a minimum calorific value), and as outputs it produces milk, methane and effluent. The cow also needs shelter, in the form of a cow shed.

In the systems dynamics model, the stocks of feed and water are converted into milk stock, by flow rates (the typical amount of water and feed a cow needs per day). We made the following simplistic assumption that if a cow does not receive sufficient water or nutrients it stops producing milk. Once sufficient feed and/or water is available, the cow will continue milk production. In our model cows do not die if food or water is unavailable, and they produce milk at a fixed rate.

Water on the farm is obtained from a dam. Annual rainfall figures were obtained from rainfall data collected on the farm. Rainwater over the catchment area of the farm fills the dam, and any excess water overflows.

The feed consists of crops grown in the pasture. The rate of growth depends on the yield of crop selected. If the crop grown on the farm is insufficient to supply the calorific value the cows require, then the food is supplemented by purchasing silage from an external supplier and using selected supermarket waste. The feed can also be supplemented with fish protein (mullet) from the aquaculture production and the addition of micronutrients that are not available on the farm.

Bio digester

The bio digester converts the effluent from the cow shed (which consists of waste water used to clean the facility, and cow manure) into nutrient-rich water that is used for aqua farming and crop irrigation. It also produces dry sterilized material that can supplement bedding for the cows.

Aqua farming

Mullet and whitebait are produced. Mullet is used as an animal feed protein for the livestock on the farm, and whitebait is a high-revenue delicacy sold to generate income.

Energy production

Methane is captured and used to generate electricity for operations on the farm. Any excess is sold back to the grid. If more electricity is required, it is purchased from the grid.

Income generation

The farmer generates money by selling milk (translated into solid weight units) and whitebait from aqua farming, as well as selling any excess electricity produced, back to the grid.

Input costs for the running of the farm is for additional silage and micro nutrients for the livestock (when required), the cost of the type of grass crop cultivated per year and electricity costs for operating the farm. We are not considering labour costs for maintenance or the day to day running expenses of the farm. Capital expenses are also not considered.

Running the model

The model is used to illustrate the potential difference between running a dairy farm with and without a bio-digester. The use of the bio-digester enables the diversification of the farm as described before.
Initially the Bio digester tick box will be unselected and

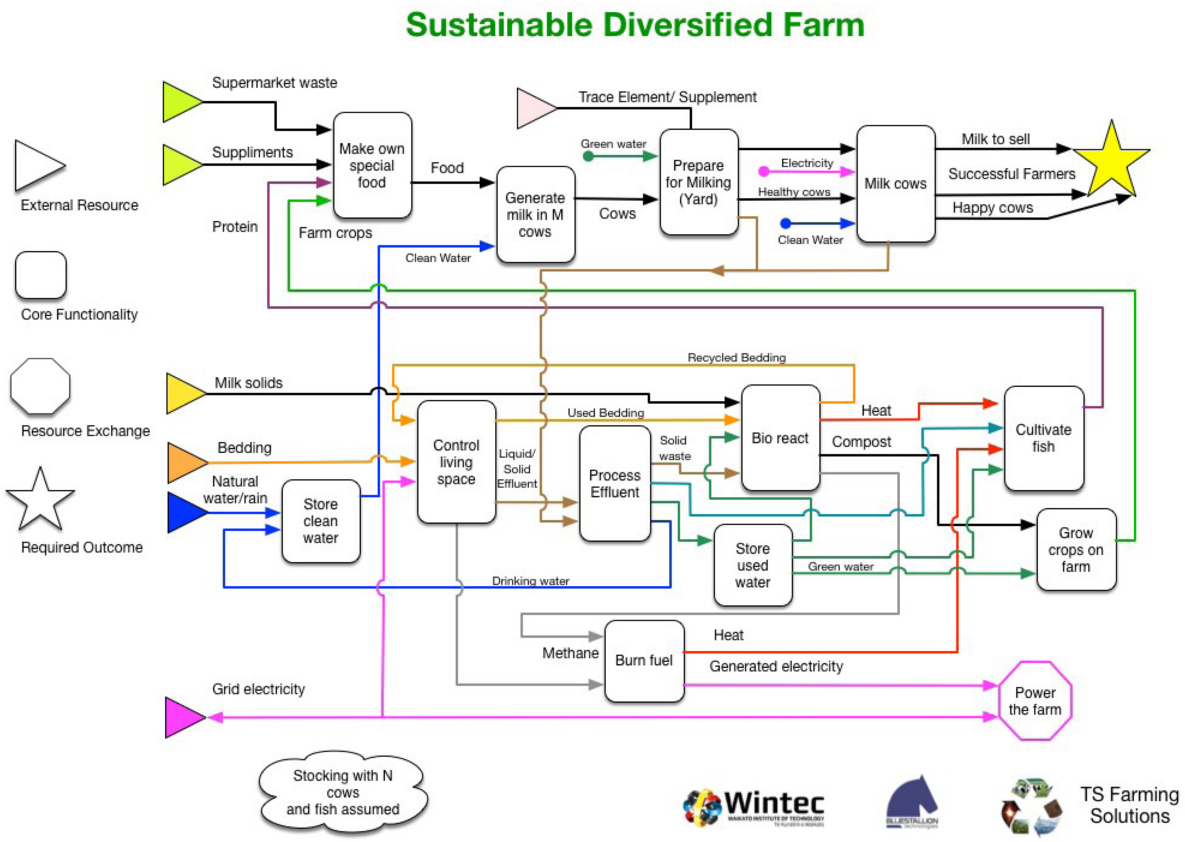

Figure 2: Concept functional diagram of Sustainable Diversified Farm (SDDF) © 2015 Wintec Rev 3.1.

the farm runs in traditional mode of operation as a dairy farm. The user will decide on the number of cows and the current milk solid price. The crop yield can also be toggled between low and high yield. The user can also decide if the feed will be supplemented by additional feed (silage). If the user selects this option, any shortfall in crop-based feed will be compensated for by purchasing externally produced feed. This will incur additional input costs, but the cows will produce milk. If this option is not selected, then cows will stop producing milk for any period when they do not have sufficient food available.

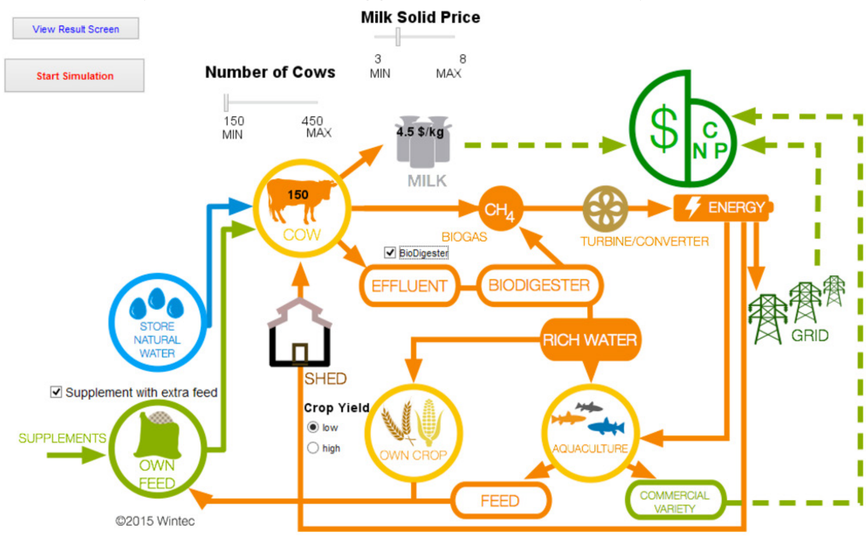

Figure 3: Input screen of the farming simulation.

The model input screen of the farming simulation is illustrated in Figure 3. The user can modify five input parameters: the number of cows on the farm, the milk solid price (in NZ Dollar), a low or high crop yield seed sown in the pasture to produce feed and a toggle to activate the Bio-digester and to supplement with external feed (silage) should the farm-produced crop be insufficient to feed the cows. The results screen of the farming model (Figure 4) shows the annual results of the simulation. Included are Income, Milk Production, Rainfall, Water availability in the reservoir, Availability of pasture, production of fish protein (if the bio-digester is selected) and grass silage (if the diet is supplemented with externally purchased feed). The total net income generated is shown in the top left of the screen. As the model runs, the Daily Results show how the milk, income and expenses for each day at a time.

The model is hosted online on http://www.runthemodel.com/. The reader is invited to explore the model interactively by varying parameters by running the simulation at: http://goo.gl/9pVfKU

Benefits of the modelling approach

The investor and farmer developed a clear understanding of the intricacies of the conversion of the farm. For example, using the functional diagram model they could estimate the initial costs of the conversion by considering the cost of each element and so operational savings could be estimated. The limit of the contribution of selling electricity to the grid became obvious and it was possible to consider the effect of varying milk solids pricing.

The modelling approach highlighted risks and assumptions very clearly and they used the model during presentations to government funding agencies to secure investment for the development of the bio-digester and partial conversion.

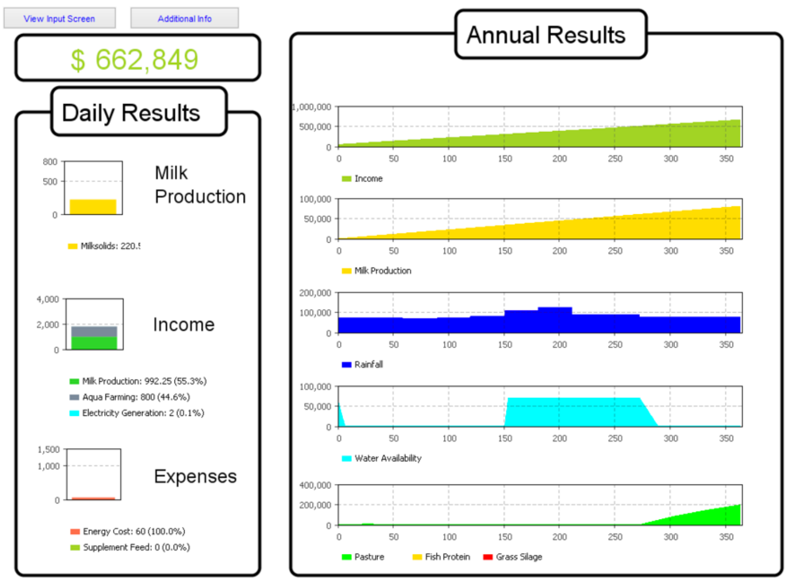

Figure 4: Results screen of the farming model

Should the farm development continue, the current model can be extended to receive inputs from external sensors to enrich the real-time picture of the status of the farm.

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Meta Modelling with Linear Programming for Capital Investment with Uncertain Returns

by Dave Evans (davevans@gmail.com)

Dave Evans

The use of multi-time period linear programme models to evaluate capital investments has been common in the petro-chemical industry for many decades. The model is usuallu set up to include the new capacity being considered, over a reasonable time scale – typically ten to fifteen years. Cases are then run with and without the capacity available, and the additional net profit from the new capacity is used in conjunction with the expected initial capital cost, to see if an acceptable internal rate of return is achieved, using discounted cash flow. In this article I consider a higher level of modelling, used in conjunction with this approach, needed in an unusual situation where it was virtually impossible to predict the profit expected from the capital investment. It is a case study from some thirty years ago. AECI had had a rather strange position as the supplier of commercial explosives (e.g. dynamite) and initiating systems (e.g. fuses and detonators) to the southern African mining industry, as it was essentially a monopoly – in both directions. Whilst AECI was for all practical purposes the only supplier, the Chamber of Mines conducted the annual pricing negotiations on behalf of the mining industry, so there was essentially only one customer, too. A further complicating factor in this situation was that in those days, the Chamber was dominated by the Anglo American Corporation, who also just happened to own more than 45% of AECI, so several of the other mining houses had their reservations about Anglo's objectivity in representing mining interests.

The government set up a Competition Board, around 1980, to make monopolistic activities more difficult. Shortly after this, a potential new manufacturer of explosives, with the implicit support of some 'non-Anglo' mining houses, took AECI and the Chamber of Mines to it, claiming it was a classic example of a monopoly which was not in the wider economic interests, and they won. AECI and the Chamber were instructed to discontinue the 'monopolistic' contract which, with variations in detail, had been in place for decades.

Faced with likely real, locally based competition, AECI began to look at ways to make itself more competitive, and the entry risks higher for new manufacturers. At this point, a digression into the way that explosives were distributed from AECI to its customers is necessary. AECI had two explosives factories; the free world's largest, at Modderfontein, near OR Tambo airport, and second largest, at Somerset West, in False Bay in the Cape. As the reader may imagine, transport of explosives around the country was very tightly regulated, by the Chief Inspector of Explosives (CIE): a department of the SA Police. Apart from a small number of mines close to the factories, where road delivery took place, everything went by rail. There was a formal, fortnightly schedule of trains from the two factories. For large mines, there could be two or three trains a week; for smaller ones, and particularly internationally, to Namibia and Zimbabwe, it could be one a fortnight. This meant that all the mines had to have large complexes of storage magazines, to stockpile the detonators and explosives to see them through the gaps between trains. These incurred significant operating costs, of course.

It occurred to us that if we set up our own decentralised factories and/or depots in the mining areas (Welkom, Klerksdorp, the Rustenburg area and the Mpumalanga coal fields), we could deliver to the mines' shafts and open pits direct, on a daily basis, and save them their magazine costs. AECI also had large enough operations that the economies of scale we would be able to achieve would be very difficult for newcomers to compete with. However, two obvious questions came up. Could we convince the CIE that this was an acceptably secure way of distributing explosives? And was it going to be economic for us to do that? A substantial capital investment was involved, of the order of R100 million in 1980s money: more than R1 billion in today's money.

This case study considers the second of those two questions. It is a classic 'with and without' situation. What will happen if we do make the investment? What will happen if we don't? The difference in net income is the return on the investment – easy? Well, not quite…

We already had linear programme models of the market and factories, which were used to allocate production and distribution. A multi-time-period version was also relatively straightforward, to cover the ten or fifteen years needed to assess the return on investment. We knew what the investment return 'hurdle' was, and therefore what incremental income was required to justify the investment. The model could easily be run in versions 'with' and 'without' the new investment, to see what would happen, IF we could estimate the market demands and what AECI's share of those would be. Estimates of the market themselves were relatively straightforward – mines operate fairly predictably for decades, so those forecasts could be provided with some confidence.

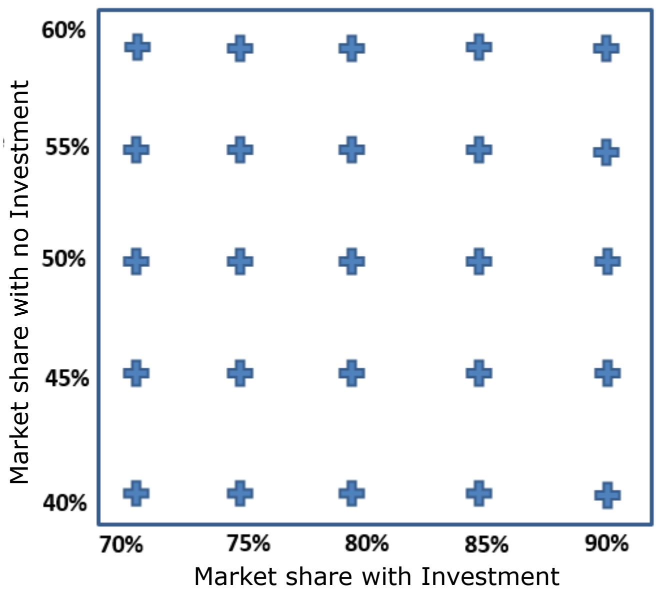


Figure 1: Market share with and with no investment grid.

Unfortunately, no-one had a clue what AECI's share of those were going to be — with or without the investment. When we asked the sales force how much of the market we were likely to lose if we did nothing, guesses ranged from '10 to 20%', up to '60 to 70%'. Likewise, if we asked how much difference the proposed new approach would make, with local factories and depots in each area, all we got were hugely varying guesses.

Then someone came up with the bright idea of the following 'meta-model'…

Any point in Figure 1 is a combination of two 'guesses' as to what the future may bring. The bottom left hand cross, for example, is two cases: one with a 40% market share if no investment takes place, compared to one with a 70% market share if the investment does take place. Likewise, the top right hand cross represents cases 'without investment' with a market share of 60% and 'with' investment with a market share of 90%. It was relatively straightforward to run the model for as many cases on each axis as the business needed in order to feel comfortable, with the relevant 'with' and 'without' market shares. The differences in net income for the various pairs from each axis, was then easily be turned into a return on investment for the capital outlay for each cross on the graph.

With these figures, we then interpolated 'iso-return' contours across the entire graph, as shown in Figure 2. As you can see, they turned out to be not quite straight lines; an aspect which we never fully worked out, but this didn't seem to upset the business people as much as it did us 'wizz-kids' in the OR Department. The thick red line shows the investment hurdle rate required in those days. Bear in mind that the South African inflation rate in those days was in the mid-teens, so 24% is not as insane as it appears today.

The star in the centre of the diagram shows the most common view of the sales and marketing staff about what were likely estimates for the 'with' and 'without' market shares. Was it all correct? We'll never know. The investment did go ahead, and AECI retained a substantial share of the market. We also convinced the CIE that shaft head deliveries could be managed securely, and that also proceeded, but that's a different story…

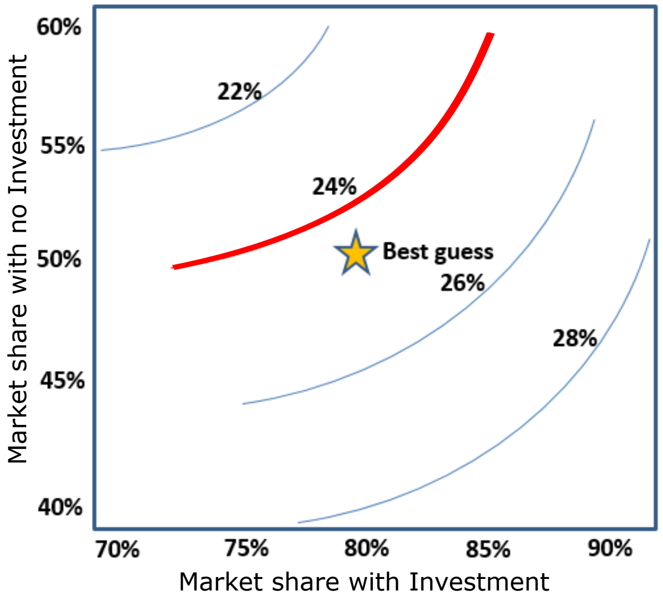


Figure 2: "Iso-return' contours.

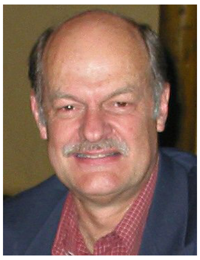
What matters more was that it had provided a framework for the business staff to explore their feelings and assumptions, firstly about their understanding of the market and the competition, and secondly, about what the company's options were on how to play in that market, going forward, and what the consequences might be. They were still looking at a space which was totally uncertain and full of very hairy 'What Ifs?', but they could play around in it, and get more comfortable with those uncertainties and their understanding of the sensitivities to the variables we could control.

Within the context of what the model could represent, if anyone had a specific scenario, we were able to evaluate that – for example, a larger market share for product X in region Y, combined with a lower one for product W in region Z, or a bigger or smaller investment in region V.

When the various investments took place, they proceeded with a degree of confidence and commitment which was a significant part of their success. As the saying goes, it isn't a case of 'Did you take the right decision?' It's more 'Did you take the decision "right"?' We thought we had contributed to the latter.

Book Review: Decision Support for Forest Management

by Hans W. Ittmann, University of Johannesburg (hittmann01@gmail.com)



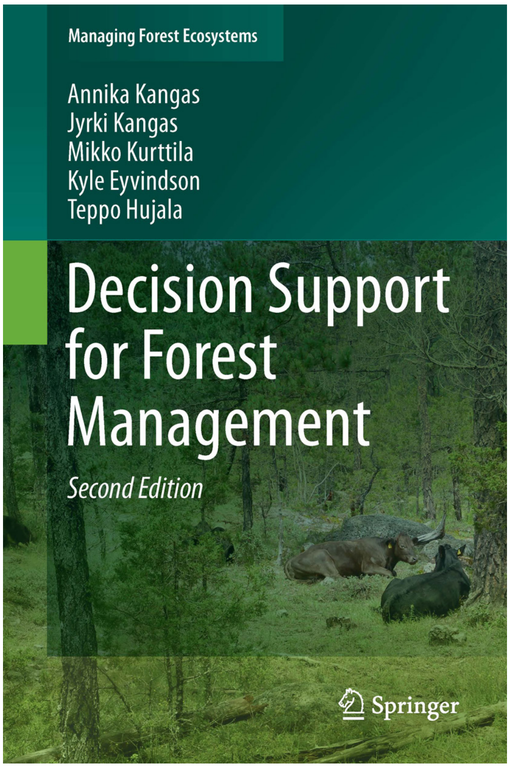
Hans Ittmann

Operations Research has been an important tool used in forestry and specifically forest management planning. It has been successfully applied and used at all levels of management decision-making, namely, strategic, tactical, and operational. Forest management planning is critical for forestry related decision-making. Strategic planning, which typically covers a planning horizon of 20 years or more (long-range planning) and is very dependent on the type of species, focusses on what is wanted from the forest. Tactical planning, covering 5 to 20 years, is aimed at how the strategic goals are to be achieved. Tactical planning considers, *inter alia*, different or alternative forest plans including stand or compartment (blocks of trees) regimes, spatial decisions such as road construction to areas that need to be harvested. Operational planning encompasses execution plans such as when to harvest a stand or compartment, volumes to be harvested, selection of harvesting equipment, transport scheduling and transporting logs to the mills for sawing or for pulping. Given the long rotation ages of timber (up to 35 years), it is important that decisions should not sacrifice long-term sustainability for short-term gains.

Decision Support for Forest Management is the 2nd edition of the book by the authors who all originate from Finland. It is based on research they have done, lectures they presented and real-life experiences in forestry planning and decision-making. In this edition more emphasis is placed on the practical aspects of multi-criteria decision-making in the forestry context as well, as participatory planning situations and the tools used for this purpose. Advanced problem formulations are included as well with examples of more advanced optimization methods and methodologies to solve these.

The book is divided into five parts. Part One covers concepts and definitions. The focus here is on planning, decision making phases and different planning problems. Forestry planning management is outlined with a special emphasis on sustainability. Sustainability as a concept is defined as well as the development of approaches to optimization and multi-criteria decisions, and the need for participatory planning.

In Parts Two and Three, discrete and continuous problems formulations are introduced in a number of chapters. The theory is explained in detail and illustrated by the use of examples. As the theory is developed, the examples used are more and more forestry related. The same problem is solved using different methods or, as the theory is enhanced, this enhancement is applied to the problem in question, which is very useful. In the first discrete problem chapter, the focus is on single-criteria problems. It is shown how to measure utility and value, how to assess risk, and how to estimate a value function. Following from this the next chapter delves into multi-criteria problems. All aspects related to decision models, multi attribute utility functions and the Analytical Hierarchy Process (AHP) are discussed comprehensively. This includes a range of technics and utility functions such as SMART and TOPSIS, the AHP, the Analytical Network Process (ANP), Even Swaps and A'WOT (using the AHP with SWOT analysis) which are applied in different examples. Uncertainty in multi-criteria decision making is dealt with as well as fuzzy set theory, outranking methods such as PROMETHEE and ELECTRE, and probabilistic uncertainty using Stochastic Multi-criteria Acceptability Analysis (SMAA). The techniques for addressing continuous problems include optimization (i.e. linear, goal, integer programming), heuristic optimization, where a whole range of heuristic methods are discussed, and uncertainty in optimization. The latter includes stochastic, robust and chance-constraint programming, and stochastic portfolio modelling. Separate sections are specifically devoted to forest planning with LPs, the general forest planning problem formulation, hierarchical forest planning, modelling, *etc.*



An interesting addition to the book is the issue of how to deal with public participation, involving various stakeholders, a phenomenon which has become very common in forest management planning situations. The public participation obviously includes the general public and other stakeholders, but there are also decision makers and facilitators involved. Group decision making and participatory planning require not only careful planning but those that facilitate these sessions should ensure that all issues are covered and the views of all those affected are considered, etc. How to design and facilitate, with different roles, a group decision process, and to measure the success of sessions are addressed in the chapter devoted to this topic. To enable real participation of all involved different voting methods and strategies have been developed for this purpose. Some of the voting approaches, that constitute the content of chapter ten, include social choice theory, positional voting schemes, pairwise voting, fuzzy voting and probability voting.

In chapter eleven examples of participatory planning processes in the context of forest management planning are presented. These cover examples from managing the forest of a city park to preparing national forest programmes. Different decision support tools and methods are discussed to handle participatory planning processes. These include problem structuring methods (Strategic Options Development Analysis (SODA), Soft Systems Methodology (SSM) and Strategic Choice Approach (SCA)), tools for eliciting public preferences and decision support for group decision making using, for example, Group Decision Support Systems (GDSS) tools for distributed group negotiations. Again examples illustrating and explaining the use of the methods and approaches, as used in the forestry environment, are scattered throughout the various chapter.

The penultimate chapter is devoted to behavioural aspects of planning, decision making and participation, including concepts as 'satisficing' or ´groupthink'. The authors make the point and try to illustrate that while people without any aid do not necessarily maximise their utility, they might, in fact make better decisions, when aided. It is also shown that decision support based on image theory (the way people perceive themselves) could provide a possible way of solving the challenge of combining behavioural and decision aid views.

Well managed forests are a renewable resource that produce essential raw material for a whole range of products and this all should be done with minimal waste and energy use. A shift from multi-functional forest management based on the principles of ecosystems diversity has been noticeable over the last number of years. Given this, making full use of technologies and new developments is therefore one of the challenges faced within the forestry industry. This book presents the advances and progress that has been made over the last forty to fifty years in the use of OR in this environment. The range of techniques, methods and approaches used has clearly grown substantially as is evident from the book *Decision Support for Forest Management*. It provides detailed exposure to a multitude of OR methods and this is enriched by forestry examples throughout the book.

Decision Support for Forest Management 2nd Edition by Annika Kangas, Mikko Kurttila, Teppo Hujala, Kyle Eyvindson and Jyrki Kangas, 2015, Springer-Verlag, Berlin, pp. 307, ISBN: 978-3-319-23521-9, EURO 149.99 (Hardcover).

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