Brief history of systems analysis in forest resources

B. Bruce Bare & Andres Weintraub

Annals of Operations Research

ISSN 0254-5330
Volume 232
Number 1

Ann Oper Res (2015) 232:1-10
DOI 10.1007/s10479-015-1897-2

Springer

Ann Oper Res (2015) 232:1–10
DOI 10.1007/s10479-015-1897-2

Brief history of systems analysis in forest resources

B. Bruce Bare[1] · **Andres Weintraub**[2]

Published online: 17 May 2015

Abstract An introduction to the special volume on Operations Research in Forestry from the 14th Symposium for Systems Analysis in Forest Resources, held at the Marbella Resort, Maitencillo, Chile, March 8–11, 2011. This volume of the *Annals of Operations Research* contains some of the papers presented at the Symposium that were submitted for publication and passed the rigorous peer review process. In addition, manuscripts were solicited from the operations research and forest resources communities to enrich the contributions for this special volume.

Keywords Symposium proceedings · SSAFR · Systems analysis · OR · Forest sector

The 14th Symposium for Systems Analysis in Forest Resources was held at the Marbella Resort, Maitencillo, Chile, March 8–11, 2011. Seventeen keynote talks and 68 contributed papers were presented within the following general categories: forest environment, long range planning, transportation and logistics, tactical spatial planning, forest fire, stochastic models, and stand-level planning. Authors of papers came from 21 countries, making this the largest of the Systems Analysis in Forest Resources symposia held to date. This volume of the *Annals of Operations Research* contains some of the papers presented at the Symposium that were submitted for publication and passed the rigorous peer review process. In addition, manuscripts were solicited from the operations research and forest resources communities to enrich the contributions for this special volume.

Some of the earliest applications of operations research to forest resource problems occurred in the late 1950s and early 1960s when linear programming (LP) was applied to a

✉ B. Bruce Bare
bare@u.washington.edu

Andres Weintraub
aweintra@dii.uchile.cl

1 School of Environmental and Forest Sciences, University of Washington, Box 352100, Seattle, WA 98195-2100, USA

2 Department of Industrial Engineering, University of Chile, Santiago, Chile

lumber grade recovery problem (Armizu 1956); plywood production and distribution (Bethel and Harrell 1957); site rehabilitation analysis (Yoho and Row 1958), and to timber harvest scheduling problems (Theiler 1959; Curtis 1962; Leak 1964). The first LP of wide use by the US Forest Service was developed by Navon (1971). The LP model of Ware and Clutter (1971) was heavily used in the private sector. Later models such as FORPLAN (Johnson et al. 1986) and SPECTRUM (USDA Forest Service 1995) were introduced to emphasize land allocation, multiple-use, and environmental considerations over earlier models.

Numerous applications of LP as well as many other operations research techniques (i.e., integer programming, goal programming, dynamic programming, nonlinear programming, simulation, decision theory, AI-expert systems, queuing theory, critical path, and other network methods) quickly followed in both the private and public sectors.

In 1975, the first Systems Analysis and Forest Resource Management Workshop was held at the University of Georgia, Athens, GA. As shown in Table 1, 38 papers were presented within the following general categories: multiple-use and land-use planning, timber management, timber harvesting and transportation, forest fire, and data management. A similar symposium followed in 1985 and subsequently at intervals of 1–3 years. Locations of the symposia have varied, with 10 being held in the United States, 3 in Chile, and 1 in Brazil. The number of papers presented at the symposia has ranged from 31 to 85 and complete proceedings have been published for 9 of the symposia while selected papers and abstracts are available for 4 of the symposia. For the 12th Systems Analysis in Forest Resources Symposium, no proceedings or abstracts have been made available (see Table 1).

Formed in 1972, the Systems Analysis Working Group, Society of American Foresters was the prime organizer of the early symposia. However, in the 1980s a forestry cluster was organized under the Energy and Natural Resources section of INFORMS and subsequently the two groups have promoted the development of operations research models for helping solve many forestry and forest industry problems. Typically, the forestry cluster organizes sessions at the INFORMS bi-annual meetings and occasionally at the International Federation of Operational Research Societies meetings.

Many operations research techniques have been used to study a variety of forest resource management problems over the 36 years since the symposia began. Advances in algorithmic efficiency, increased computational capabilities, and comprehensive and easily updated information systems have allowed researchers and analysts to develop ever more complex and realistic models. In addition, while forest planning, transportation, fire and fuel management, and timber harvest scheduling remain important areas of study, it is clear that new applications of operations research are moving forward as well. For example, recent symposia have included papers dealing with the maintenance or enhancement of biodiversity, spatial forest planning, risk assessment, ecological management, carbon sequestration, and other environmental services and forest assessments. This clearly demonstrates that forest researchers and analysts are orienting their modeling efforts to address contemporary forest management issues of importance to the forestry profession as well as to society.

Since the early days of operations research, applications of operations research to forestry problems have expanded from the use of single objective models to include a variety of multiple objective as well as fuzzy programming models. This necessarily reflects society's perception that forests are used for multiple purposes which are supported by multiple user groups. Incorporating uncertainty and risk into these models has proved to be a daunting task resulting in fewer applications in this area (Martell et al. 1998; Badilla-Veliz et al. 2014). However, working with the long time frames associated with forest systems, it is clear that additional effort should be devoted to this area of research. Perhaps one reason for the lack

Table 1 History of Systems Analysis in Forest Resources Symposia

Number	Date	Location	Sponsor(s)	Number of papers	Proceedings	Title	Published by	Editors
1	August 11–13, 1975	University of Georgia	Systems Analysis Working Group, SAF	38	Yes	Systems Analysis and Forest Resource Management	Society of American Foresters	John Meadows
		Athens, GA	SE For Expt Sta, USFS					Bruce Bare
			Schl For Res, U of GA					Ken Ware
								Clark Row
2	December 9–11, 1985	University of Georgia	Systems Analysis Working Group, SAF	49	Yes	1985 Symposium on Systems Analysis in Forest Resources	GA Ctr for Continuing Educ. (1987)	Peter Dress
		Athens, GA	Schl For Res, U of GA					Richard Field
			USDA, Forest Service					
			ORSA					
			TIMS					
3	March 29–April 1, 1988	Asilomar Conf. Ctr	Dept of Forestry & Res. Mgt, U of CA	40	Yes	1988 Symposium on Systems Analysis in Forest Resources	USDA, FS, Rocky	Brian Kent
		Pacific Grove, CA	Systems Analysis Working Group, SAF				Mtn For Expt Sta,	Larry Davis
			USDA, Rocky Mtn For Expt Sta				GTR-RM-161	
			USDA, Land Mgt Planning				(1988)	

Table 1 continued

Number	Date	Location	Sponsor(s)	Number of papers	Proceedings	Title	Published by	Editors
4	March 3–6, 1991	Charleston, SC	Systems Analysis Working Group, SAF	65	Yes	1991 Symposium on Systems Analysis in Forest Resources	USDA, FS, SE	Marilyn Buford
			USDA, SE For Expt Sta				For Expt Sta	
			Westvaco				GTR-SE-74	
			NC State University				(1991)	
			For Products Res Society				http://treesearch.fs.fed.us/pubs/924	
			TIMS					
5	March 9–12, 1993	Villa del Rio Conf. Ctr	For Mgt Inst.,Univ. Austral of Chile	48	Yes	Int'l Symposium on Systems Analysis and Mgt Decisions in For	Austral Univ	Gonzalo Paredes
		Valdivia, CL	Dept of Ind Engr, Univ. Of Chile				Valdivia, Chile (1994)	
6	September 6–9, 1994	Asilomar Conf. Ctr	Systems Analysis Working Group, SAF	49	Yes	1994 Symposium on Systems Analysis in Forest Resources	Society of American Foresters	John Sessions
		Pacific Grove, CA	Dept of For Engr and For Res, OR St Univ				http://www.ipef.br/publicacoes/stecnica/nr35.asp	Douglas Brodie
			USDA, FS					

Table 1 continued

Number	Date	Location	Sponsor(s)	Number of papers	Proceedings	Title	Published by	Editors
7	May 28–31, 1997	Shanty Creek Resort	Systems Analysis Working Group, SAF	65	Yes	Seventh Symposium on Systems Analysis in Forest Resources	USDA, FS, NC	Michael Vasievich
		Traverse City, MI	MI St University				For Expt Sta	Jeremy Fried
			USDA, NC For Expt Sta				GTR-NC-205	Larry Leefers
							http://www.nrs.fs.fed.us/pubs/269	
8	September 27–30, 2000	Snow Mass Village	Systems Analysis Working Group, SAF	31	Yes	Systems Analysis in Forest Resources	Kluwer Academic Publishers, The Netherlands, (2003)	Greg Arthaud
		Aspen, CO	USDA, Pac SW For Expt Sta, Fire Lab				http://www.springer.com/life+sciences/forestry/book/978-90-481-6280-2	Tara Barrett
			USDA, Rocky Mtn For Expt Sta					
			Yale School of For and Environment					
			USDA, FIA, Pac NW For Expt Sta					

Table 1 continued

Number	Date	Location	Sponsor(s)	Number of papers	Proceedings	Title	Published by	Editors
9	March 4–7, 2002	Punta de Tracla, Chile	IFORS	51	Yes (select papers/ abstracts)	Symposium on Models and Systems in Forestry	Int'l J of OR Vol 10(5): 409–542 (2003)	Robert Haight
			IUFRO (Sec 5.13)				http://www.dii.uchile.cl/~sympfor/CD/index2.html	Andres Weintraub
			Dept of Ind Engr, Univ. of Chile					
			Ctr for Math Modeling, Univ. of Chile					
10	October 7–9, 2003	Skamania Lodge	Systems Anal, For Econ, Policy, Law,	42	Yes	Systems Analysis in Forest Resources: Proceedings of the 2003 Symposium	USDA, FS, PNW	Michael Bevers
		Stevenson, WA	Tech Assessment and Future Anal				For Expt Sta	Tara Barrett
			Working Groups, SAF				GTR-PNW-656	
			IUFRO				(2005)	
			College of Forestry and Dept of Stat, OSU				http://www.fs.fed.us/pnw/publications/pnw_gtr656/	
			Western For and Cons Association					
			USDA, FS, PNW For Expt Sta, FIA Unit					
			Rocky Mth For Expt Sta					

Table 1 continued

Number	Date	Location	Sponsor(s)	Number of papers	Proceedings	Title	Published by	Editors
11	September 18–21, 2005	Recanto das Toninhas Hotel Ubatuba, Brazil		58	Yes (partial w/abs)	Proceedings of the 3rd Iberian Am. Symposium on For Management and Economics and 11th SSAFR	Serie Tecnica, Inst. de Pesquisas e Estudos Florestals, Issue No. 35 http://www.ipef.br/publicacoes/stecnica/nr35.asp	Luiz Rodriguez
12	September 5–8, 2006	Inn at Essex Burlington, VT	Arkansas Forest Resources Center	45	No	12th Symposium for Sys Anal in Forest Resources	List of papers: http://faculty.washington.edu/bare/2006SSAFRprogram.pdf	

Table 1 continued

Number	Date	Location	Sponsor(s)	Number of papers	Proceedings	Title	Published by	Editors
13	May 26–29, 2009	Frances Marion Hotel	Society of American Foresters	35	Yes (four select papers)		Int'l J of Math and Computational For and Nat'l-Res Sci Vol 2, Nos. 1 and 2	Marc McDill
		Charleston, SC	ArborGen North Carolina State University				http://mcfns.com/index.php/Journal/article/view/MCFNS.2-41/MCFNS_2%3A41-42	
14	March 8–11, 2011	Marbella Resort	Instituto Sistemas Complejos de Ingenieria	85	Yes (abstracts only) (selected papers in Annals of Operations Research)	14th Symposium for Systems	Presentations at:	Andres Weintraub et al.
		Maitencillo, Chile	Iniciativa Cientifica Milenio Comision Nacional de Investigacion Centifica Tecnologica Facultad de Ciencias Fisicas Matematicas and Ingenieria Industrial, Univ. de Chile Forestal Mininco Arauco INFORMS EURO			Analysis in Forest Resources	http://faculty.washington.edu/bare/SSAFR2011	

of application of such tools is the difficulty forest resource managers have interpreting model results that yield a distribution of model outputs instead of a single numerical result.

To reduce problem size, as well as to better represent real-world decision environments, many varieties of hierarchical planning models have been developed. Typically, feedback linkages are developed between the strategic and tactical planning models to facilitate model solutions. Many tactical planning models incorporate binary decision variables in recognition of the requirement to: (a) schedule treatments on whole land units, (b) not treat adjacent land units in the same or subsequent time period, (c) allow only a certain area of contiguous land to be treated in a given time period, or (d) to facilitate incorporation of road building activities into the model. Because integer models are inherently difficult to solve to optimality, many heuristic algorithms have been introduced to derive good—satisfactory solutions when measured against an LP upper bound. These heuristic algorithms allow analysts to develop more realistic models than some of the earlier applications that could be solved to optimality.

A rich collection of survey articles and bibliographies exists to guide the interested reader into the history of the application of operations research techniques to a large array of forestry and natural resource problems. A selection of these studies is located at the conclusion of this introduction.

References

Armizu, T. (1956). Application of linear programming to forestry. *Tokyo University Forest*, *11*, 49–76.

Badilla-Veliz, F., Watson, J.-P., Weintraub, A., Wets, R. J.-B., & Woodruff, D. L. (2014). Stochastic optimization models in forest planning: A progressive hedging solution approach. *Annals of Operations Research*,. doi:10.1007/s10479-014-1608-4.

Bethel, J. S., & Harrell, C. (1957). The application of linear programming to plywood production and distribution. *Forest Products Journal*, *7*, 221–227.

Curtis, F. H. (1962). Linear programming the management of a forest property. *Journal of Forestry*, *60*, 611–616.

Johnson, K. N., Stuart, T., & Crim, S. A. (1986). *FORPLAN, version 2: An overview*. Washington, DC: USDA Forest Service, Land Management Planning Systems Section.

Leak, W. B. (1964). Estimating maximum allowable timber yields by linear programming. USDA Forest Service, RP-NE-17, Northeastern Forest Experiment Station, Upper Darby, PA.

Martell, D. L., Gunn, E. A., & Weintraub, A. (1998). Forest management challenges for operational researchers. *European Journal of Operational Research*, *104*(1), 1–17.

Navon, D. I. (1971). Timber-RAM, a long range planning method for commercial timber lands under multiple-use management. USDA Forest Service, RP-PSW-70, Pacific Southwest Forest Experiment Station, Berkeley, CA.

Theiler, T. (1959). Linear programming and optimal cutting practices. *American Paper Industries*, *41*(6), 384–388.

USDA Forest Service. (1995). Ecosystem management, strategic planning and SPECTRUM. *Analysis Notes*, *5*(1), 1–4.

Ware, G. O., & Clutter, J. L. (1971). A mathematical programming system for the management of industrial forests. *Forest Science*, *17*, 428–445.

Yoho, J. G., Row, C. H. (1958). Methods for evaluating rehabilitation programs by linear programming. In *3rd Conference on Industrial Forest Management, Duke University* (pp. 92–104).

Surveys of applications of operations research in forestry and the forest industries

Bare, B. B. (1971). Applications of operations research in forest management: A survey. Center for Quantitative Science in Forestry, Fisheries and Wildlife, Quantitative Science Paper 26, University of Washington, Seattle, WA.

Bare, B. B., Briggs, D. G., Roise, J. P., & Schreuder, G. F. (1984). A survey of systems analysis in forestry and the forest products industries. *European Journal of Operational Research*, *18*(1), 1–18.

Dykstra, D. P. (1984). *Mathematical programming for natural resource management. McGraw-Hill series in forest resources*. New York: McGraw-Hill.

de Steiguer, J. E., Liberti, L., Schuler, A., & Hansen, B. (2003). Multi-criteria decision models for forestry and natural resources management: An annotated bibliography. USDA Forest Service GTR-NE-307, Northeastern Experiment Station, Newton Square, PA.

Gordon, S.N., Johnson, K.N., Reynolds, K.M., Crist, P., Brown, N. (2004). Decision support systems for forest biodiversity evaluation of current systems and future needs. Final Report-Project A-10, National Commission on Science and Sustainable Forestry. (http://ncseonline.org/sites/default/files/A10%20final%20report.pdf)

Harrison, T. P., & de Kluyver, C. A. (1984). MS/OR and the forest products industry. *Interfaces*, *14*(5), 1–7.

Helles, F., Anderson, P. H., & Wichmann, L. (Eds.). (1999). *Multiple use of forests and other natural resources* (Vol. 61), Forestry Sciences. Dordrecht: Kluwer Academic Publication.

Hof, J. (1993). *Coactive forest management*. London: Academic Press.

Hof, J., & Bevers, M. (1998). *Spatial optimization for managed ecosystems. Complexity in ecological systems series*. New York: Columbia University Press.

Kallio, M., Anderson, A. E., Seppala, R., & Morgan, A. (Eds.). (1986). *Systems analysis in forestry and forest industries* .(Vol. 21), Studies in the management sciences. Amsterdam: Elsevier Science Publication.

Martell, D. A. (1982). A review of operational research studies in forest fire management. *Canadian Journal of Forest Research*, *12*(2), 119–140.

Martell, D. L. (2007). Fifty years of OR in forestry preface to the special forestry issue of INFOR. *INFOR: Informational systems and Operational Research*, *45*(1), 5–7.

Martell, D. L. (2007). Forest fire management: Current practices and new challenges for operational researchers. In A. Weintraub, C. Romero, T. Bjørndal, R. Epstein, & J. Miranda (Eds.), *Handbook of operations research in natural resources* (Vol. 99, pp. 489–509), International series in operations research and management science. New York: Springer.

Martell, D. L. (2009). The development and implementation of forest fire management decision support systems in Ontario, CA: Personal reflections on past practices and emerging challenges. *Mathematical and Computational Forestry and Natural-Resource Sciences*, *3*(1), 18–26.

Martin, A. J., Sendak, P. J. (1973). Operations research in forestry: A bibliography. USDA Forest Service, GTR-NE-8, Northeastern Forest Experiment Station, Upper Darby, PA.

Mowrer, H.T. (ed). (1997). Decision support systems for ecosystem management: An evaluation of existing systems. USDA Forest Service GTR-RM-296, Rocky Mountain Forest and Range Experiment Station, Fort Collins CO.

Romero, C., & Rehman, T. (1987). Natural resource management and the use of multiple criteria decision-making techniques: A review. *European Review of Agricultural Economics*, *14*(1), 61–89.

Row, C., & Schmelling, B. (1971). *Resource information planning systems: A catalog of computerized systems in the USDA forest service*. Washington, DC: USDA Forest Service.

Schopfer, W., & Hofle, H. (1970). *Operations research: A bibliography of applications in forest management and forest products manufacturing*. Der Baden-Wurttembergischen. Forstlichen Versuchs-und Forschungsanstalt, Heft 25.

Schuster, E. G., Leefers, L. A., & Thompson, J. E. (1993). A guide to computer-based analytical tools for implementing national forest plans. USDA Forest Service GTR-INT-296, Intermountain Research Station, Ogden, UT.

Weintraub, A., & Romero, C. (2006). Operations research models and the management of agricultural and forestry resources. *Interfaces*, *36*(5), 446–457.

Weintraub, A., & Bare, B. B. (1996). New issues in forest land management from an operations research perspective. *Interfaces*, *26*(5), 9–25.