USE OF SPATIAL OPTIMISATION METHODS FOR LANDSCAPE-LEVEL FUEL TREATMENT PLANNING

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Background

In recent years an increase in the extent and severity of wildfires has been observed across the globe. High fuel loads arising in part from modified fire regimes have been a contributing factor in many severe fires. Prescribed burning and other fuel reduction treatments are among the few options available to fire and land management agencies as they seek to reverse this trend. However, fuel treatment planning is a highly complex undertaking with questions arising as to the optimal extent, spatial location, timing and types of fuel treatment to apply.

Problem Structure

- Spatial optimisation problem
- Landscape-level fuel treatment planning
- Multi-year planning horizon
- Multiple objectives - community protection, ecological
- Risk considerations - likelihood and consequence of fire
- Fuel regrowth dynamics – inhibitory effect and persistence of fuel treatment
- Operational, ecological and cost constraints

Optimisation Model

Objective function includes a community protection and an ecological term

$$\text{MIN} \quad \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} IgnitionProb_{ij} * A_{tij} * Values_{ij} + P\left(\sum_{t=1}^{T} DeficitMid_t + \sum_{t=1}^{T} DeficitLate_t\right)$$

Constraints include:

Annual treatment budget

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Treat_{tij} * TreatCost_{tij} \le TreatBudget_t \qquad \forall t \in T$$

Annual area treated limit:

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Treat_{tij} * Area_{ij} \le TreatAreaLimit_t \qquad \forall t \in T$$

Fuel age resets to zero if a cell treated:

$$FuelAge_{tij} - MaxFuelAge * (1 - Treat_{tij}) <= 0 \qquad \forall t \in T \quad \forall i \in I \quad \forall j \in J$$

Fuel age increments by one if a cell is not treated:

$$FuelAge_{tij} - FuelAge_{(t+1)ij} + MaxFuelAge * (1 - Treat_{(t+1)ij}) <= MaxFuelAge - 1 \qquad t = 1,..,T-1 \quad \forall i \in I \quad \forall j \in J$$

$$FuelAge_{tij} - FuelAge_{(t+1)ij} + MaxFuelAge + 1 \ge MaxFuelAge * (1 - Treat_{(t+1)ij}) \qquad t = 1,..,T-1 \quad \forall i \in I \quad \forall j \in J$$

Minimum tolerable fire interval:

$$Treat_{tij} * MinTFI_{ij} <= FuelAge_{(t-1)ij} \qquad t = 2,..,T \quad \forall i \in I \quad \forall j \in J$$

Maximum tolerable fire interval:

$$FuelAge_{tij} <= MaxTFI_{ij} \qquad t = 2,..,T \quad \forall i \in I \quad \forall j \in J$$

Targets for proportions of the landscape in the mid and late PFSS expressed as goal constraints

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Late_{tij} * Area_{ij} + DeficitLate_t \ge DesiredLate * TotalArea \qquad \sum_{i=1}^{I}\sum_{j=1}^{J} Mid_{tij} * Area_{ij} + DeficitMid_t \ge DesiredMid * TotalArea \qquad \forall t \in T$$

Computational Test Results

- Model tested for functionality
- Randomly generated test landscapes - each 100 Cells, 10 time periods
- Problem Size -39,600 Variables , 23,500 Constraints, 56,500 Coefficients
- Solved with CPLEX 12.2 to optimality in 10-15 mins (Intel 2Duo 2.10 GHz 2.00 GB RAM)
- Promising initial results suggest the modelling framework is capable of tackling realistic sized problems

Future Work

- Fire simulation to aid model parameterization - expected fire footprints, treatment effect on fire behaviour
- Accounting for unplanned fire - stochastic programming, mean value
- Exploring various planning horizons, replanning intervals

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