Tahoe Research Supported by the SNPLMA Program, RFP 2008

I. Title Page

Project Title	**Integrated Decision Support for Cost Effective Fuel Treatments Under Multiple Resource Goals**	
Theme and sub-theme	Theme	Effects of Wildfire and Fuel Treatments
	Sub-theme	Evaluating alternatives for fuel treatments
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II. Proposal Narrative

Project Abstract

Many communities in the Lake Tahoe Basin are at high risk for damage from wildfire. The USDA Forest Service Lake Tahoe Basin Management Unit (LTBMU) and other land management agencies in the Basin have collectively developed multi-jurisdictional fuel reduction and wildfire prevention strategies (LTBMU 2007) to address severe wildfire threats. Such strategies, however, have not yet been thoroughly evaluated in terms of fuels treatment effects on fire behavior, water quality, ecosystem processes, as well as their cost effectiveness. There are a number of models that can address some of these effects independently, but the collective effects of fuels treatments have been neither addressed, nor incorporated into a decision making system for fuels management in the Basin. There is a critical need to merge these systems into one decision support tool that streamlines analyses for identifying where, when, and how to treat to maintain desired fuel reduction and ecological goals, while meeting given resource and operational constraints.

We propose a 2.5-year project to develop an integrated decision support system and apply it in the Lake Tahoe Basin. Building upon two current research projects by the PI and Co-PIs, our support system will combine the vegetation simulation capabilities of FVS-FFE, the fire behavior capabilities of FlamMap, the water quality prediction capabilities of FS WEPP, and the spatial scheduling and cost effectiveness analysis capabilities of MAGIS into one system. This will provide land managers the ability to spatially schedule fuel treatments on a landscape and to also analyze tradeoffs of different management strategies. Users will have to learn one seamlessly integrated system to develop the most cost effective way of maintaining fuel treatments in the Basin, while simultaneously addressing treatment effects on fire behavior, water quality and ecosystem restoration. Our research thus addresses Sub-theme “Evaluating alternatives for fuel treatments” under Theme 1 of Lake Tahoe Research RFP 2008.

1. Justification

Lake Tahoe is a national treasure and an area of national concern. Due to environmental damages caused by past land use practices and development, Lake Tahoe’s water clarity has significantly diminished (Goldmann 1988), and a large portion of the Lake Tahoe Basin has a high-risk of severe wildfires (TRPA 2007). The USDA Forest Service Lake Tahoe Basin Management Unit (LTBMU) considers catastrophic wildfire a significant threat to the natural resources, scenic qualities, communities and economic values within the Lake Tahoe Basin, including lake water quality (LTBMU 2006). Reducing catastrophic wildfire risk is a priority in the LTBMU, and fuels reduction is recognized as an essential tool for enhancing forest health conditions, habitat, and watershed quality, as well as reducing fire risks (LTBMU 2006, Murphy et al. 2007).

In response to the elevated threat of high intensity wildfire and needs of ecosystem restoration in the Basin, the Forest Service-LTBMU has treated 21,000 acres of fuels since 1977 through the Environmental Improvement Program (EIP). In addition, the LTBMU has developed fuels treatment plans for over 68,000 acres of forested areas within the Basin for next 10 to 15 years (TRPA 2007, LTMBU 2007). Although major effort has begun to address excessive fuel loads in Lake Tahoe Basin forests, the existing fuel treatment plans and management strategies have not been thoroughly examined nor refined in terms of 1) their effectiveness in changing fire behavior, 2) longevity of effects of fuels treatment and strategies for maintaining desired effects overtime, 3) cost effectiveness in fuels treatment and slash disposal, and 4) effects of fuels treatment on forest ecosystem and water quality.

A number of models and tools have been developed and extensively validated for addressing the effects and effectiveness of fuel treatments from different perspectives and geographic scales. For example, FARSITE (Finney 1998) and FlamMap (Finney 2006) are able to compute fire behavior characteristics at a landscape scale. However, neither temporal effects of treatments nor maintenance scheduling are included in either of these models. FVS-FFE (Reinhardt and Crookston 2003) has the ability to model stand-level fuel and vegetation dynamics, but it does not simulate the spread of fires between stands. As an economic optimization tool, MAGIS (Multiple-resource Analysis and Geographic Information System; Zuuring et al. 1995, Chung et al. 2005, Jones et al. 1986) has the ability to optimize forest treatments spatially and temporally in the presence of multiple objectives and constraints, but no fire spread logic exists in the system. FS WEPP (Elliot 1999, Elliot and Foltz 2001) is able to compute the amount of soil loss along a hillslope, as well as the sediment yield and runoff at the bottom of the hillslope, but it neither simulates fuels treatment options, nor takes into account vegetation changes by itself. The Landscape Management System (LMS; McCarter et al. 2007) is designed to assist in landscape level analysis and planning of forest ecosystems by providing stand projection and visualization functions, but it does not optimize vegetation treatments.

Forest managers have to use these multiple systems to fully analyze effects of fuel treatments on changes in fire behavior, cost effectiveness, and ecosystem functioning. However, lack of time and resources to maintain and operate these sophisticated systems and the complexity of intertwined relationships and cross-scaling among systems has been a barrier. Consequently, there is a critical need to merge these systems into one easy-to-use decision support system that 1) facilitates seamless data transfer among the existing models, 2) streamlines analyses for identifying where, when, and how to treat to achieve and maintain desired fuel reduction and forest restoration goals, and 3) bridges the gap between scientific research and on-the-ground management by incorporating given resource and operational constraints (e.g. budgets, limited access, stream environment zones (SEZs), slash disposal, and operational feasibility of treatment methods) into decision-making processes.

We propose to fill this critical need by 1) developing an integrated decision support system for the Lake Tahoe Basin that is built on existing models that optimizes fuel treatment locations in time and space for user-specified management goals and constraints, 2) working with LTBMU and other land management agencies in the Basin to develop applications of the system for the Lake Tahoe Basin using existing datasets, and 3) providing end products which include analytical tools and results. Our research thus addresses Sub-theme “Evaluating alternatives for fuel treatments” under Theme 1 of Lake Tahoe Research RFP 2008.

Our project is unique in that we will address the following landscape-level considerations of fuel treatments that are essential for fuels management and forest restoration: 1) how the spatial arrangement of treatment units (e.g., WUI vs. non-WUI treatments, steeply sloped terrain vs. gentle terrain, spatial patterns of treatment units) affects subsequent wildfire behavior across landscapes consisting of stands with varying site potential and history that lead to different fire behavior and effects potentials, 2) how long the effects of fuel treatments will last given temporal and spatial changes in fuel and vegetation on a landscape, 3) how the spatial and temporal arrangement of fuel treatments and treatment intensities affect the amount of sediment introduced to stream channels, and 4) what is the most cost-effective way of allocating and maintaining fuel treatments, as well as handling biomass, to achieve fuel management and restoration goals across the Lake Tahoe Basin with limited resources.

Given that land managers have the ability to treat only a small percentage of acres in need of treatment each year, it is extremely important that treatments be strategically placed and maintained so as to realize the greatest benefit in reducing fire risk and achieving forest restoration goals. Our approach will provide science-based yet field applicable information to land managers and policy makers who are searching for effective and efficient ways of managing fuels in the Lake Tahoe Basin and other large forested land areas. Federal agencies that manage large contiguous lands, such as the Forest Service, would most benefit from the system. However, communities and federal agencies that often manage fragmented and scattered lands, such as BLM, BIA, or private land owners, would also profit because fuels treatment and maintenance strategies can be collectively analyzed and developed at a large scale. This integrated system will also allow managers to analyze trade-offs between different fuels management strategies, and develop clear, quantitative fuels objectives for the Basin, which can be used for effective communication with the public and other agencies.

2. Background and Problem Statement

Planning and implementing fuels treatments in the Lake Tahoe Basin presents unique challenges. First, Comstock logging resulted in overstocked forests with a substantially higher proportion of White Fir, and a lower proportion of fire resistant Jeffery Pine than were present historically (Taylor 2004). Second, the proximity of these resulting forests to populated areas, the importance of tourism, smoke dispersion, and narrow windows for effective burning conditions have limited the use of prescribed burning as a fuel management option (Stanton and Dailey 2007). Third, due to steep sloped areas and the sensitive nature of SEZs, most fuel treatment work has been performed by hand crews with chain saws, which reduces the cost-efficiency of treatments (TRPA 2007). Fourth, the collective effects over time of fuel treatment options on fire behavior, water quality, and ecosystem health have been little studied at the entire Basin scale. Fifth, fuels treatments have been designed and implemented with varying degrees of success to support multiple management requirements including fuel reduction and forest restoration. Sixth, treatment areas prioritized by agencies operating in the Basin (LTBMU 2007) have not been thoroughly evaluated nor refined in terms of their cost effectiveness, and effects on fire behavior, water quality and ecosystem restoration.

There exist a number of models that can address some of these challenges independently, but the collective effects of fuels treatment and forest restoration activities have been neither addressed, nor incorporated into a decision making system for fuels management in the Basin. We propose to integrate existing fire behavior, vegetation simulation, erosion prediction, and land management planning tools into one system with seamless data transfer between models. With this system, land managers will have the ability to spatially schedule fuel treatments on a landscape and to also analyze tradeoffs between different management strategies (e.g., fuel reduction goal vs. forest restoration goal, treatments in WUI vs. wildland, treatments in steep areas vs. gentle areas). The location and arrangement of the treatment units will be optimized to achieve the largest reduction in fire-related loss on the landscape, or selected portions of the landscape such as WUI, while satisfying the user-specified forest restoration and water quality goals, and resource constraints. This will be accomplished within one modeling system with GIS interfaces for both input and output displays. Users will have to learn only *one* system, and one integrated system can perform analyses more efficiently than *multiple* modeling systems used sequentially.

3. Project Objectives

3.1 Develop an integrated decision support system built on the existing models that optimize fuel treatment locations in time and space to achieve multiple management objectives while meeting resource and operational constraints. Management objectives will be implemented in a flexible manner and can include the reduction of the probability of catastrophic fire, the reduction of sediment inputs into Basin streams, the promotion of species of special concern, among others. The system (referred to as FMLTB (Fire-MAGIS for Lake Tahoe Basin)) will identify where, when, and how to treat fuels to maintain desired fuel reduction, forest restoration, and water quality goals at a landscape scale. ***Hypothesis***: This integrated decision support system can provide cost effective fuel treatment locations and methods while meeting ecological concerns and operational constraints.

3.2 Develop applications for the Lake Tahoe Basin. Working closely with land managers in the Basin, we will develop spatial and temporal fuel treatment schedules for the Lake Tahoe Basin that meet local resource management objectives. We will document the developed approach, experiences, and analysis results. We will also evaluate the system outputs in terms of the feasibility of implementation and improvement in treatment benefits.

3.3 Deliver FMLTB to end users. Built on the existing MAGIS user interface, FMLTB will be immediately deliverable to land managers in the Basin. Managers will be able to construct planning models and conduct trade-off analyses between various management strategies through workshops, meetings, and working together with us during the project period.

4. Approach, Methodology, and Geographic Location of Research

4.1 Develop an integrated decision support system

We will use the MAGIS framework in the development of FMLTB. MAGIS is an economic optimization model that has the capacity to incorporate the vegetative model as well as stand and treatment unit GIS data, set up problem parameters (e.g., management objectives and resource constraints), build the matrix of costs and effects of potential treatments, and optimize treatment schedules. FMLTB will combine MAGIS with 1) FVS-FFE to simulate fuel dynamics and stand-level treatment effects over time, 2) FlamMap, a raster-based fire behavior model, to evaluate landscape-level effects of spatial fuel treatments in each time period, 3) FS WEPP to predict soil erosion caused by potential treatments, and 4) LMS/ENVISION to enhance visualization of treatment schedules and effects across a landscape (Figure 1). The overall system design and structure to be employed in FMLTB follows the conceptual design of the Interagency Fuels Treatment – Decision Support System recently developed by the Joint Fire Science Program Fuels Working Group (JFSP 2008).

Two current research projects by the PI and Co-PIs of this project have been investigating automatic linkages among the existing fire behavior, vegetation growth, soil erosion, and economic optimization models. One research project funded by the USDA/DOI Joint Fire Science Program (JFSP) is devoted to developing a landscape-level decision support system that optimizes spatial and temporal fuels treatment schedules by linking MAGIS with FVS-FFE and FlamMap. The other research effort is testing a method for incorporating sediment predictions from the FS WEPP model into MAGIS. Both projects will be completed by the end of 2009, and will be used to provide an overarching framework for this project. Modifications to the framework for this project include 1) developing data transfer interfaces between FS WEPP and MAGIS and between MAGIS and LMS/ENVISION, 2) modifying the current MAGIS heuristic optimizer[1] to evaluate spatial and temporal fuel treatment effects and schedule long-term fuel management activities using a specific objective function and a set of constraints that can limit the amount of sediment delivery from treatments and flexibly promote forest restoration objectives. Detailed methods are described below.

MAGIS, FVS-FFE, and FlamMap

Using the MAGIS user-interface, users can develop different fuel treatment methods and enter their estimated acre-based treatment costs that can be applied to stands that meet defined criteria (e.g., forest type, watershed, SEZs, ownership, topographic conditions, etc.) for the prescription. These prescriptions may include multiple entries of treatments depending on vegetation growth predicted by FVS. A data transfer interface between MAGIS and FVS-FFE is being developed in the previously discussed JFSP project that 1) identifies all the treatment-timing combinations available for each stand, 2) converts silvicultural prescriptions into the FVS readable format, and 3) runs FVS-FFE in a batch mode to project vegetative changes with and without treatment and calculate the resulting fuel load parameters (crown base height, crown bulk density etc.) that will be used to compute fire behavior values by FlamMap (http://fire.org/). FVS will be also used to estimate the wood volumes produced by treatments by log size and species for use in analyzing biomass utilization and disposal options.

In FMLTB, we will measure the effectiveness of a fuel treatment in terms of its contribution to fire behavior change across a landscape under a specific set of fire scenarios. A fire scenario is defined as fire that originates at one or more user-specified locations and burns under user-specified conditions for wind direction and speed and burning percentile as measured by energy release. To estimate these model parameters, we will consult with land managers in the Basin and use the existing fire and weather history in the Basin (Murphy and Knopp 2000). A set of candidate fuel treatment units developed by the MAGIS heuristic optimizer (described in the following section) will collectively form a spatial pattern of fuels treatments draped over the physical template of the landscape (e.g., topography). The effectiveness of the spatial pattern will then be measured by changes in fire behavior (e.g., flame length, fire intensity, spread rates, etc.). FlamMap will be used to compute fire behavior values for the Lake Tahoe Basin using data layers consisting of fuels, topography, and weather conditions. To run FlamMap from MAGIS, we will use the result of our JFSP project that develops a data transfer interface between MAGIS and FlamMap.

MAGIS and FS WEPP

This project will link MAGIS and FS WEPP technologies. We will build a FS WEPP database to contain the common practices for fuel management in the Tahoe Basin and estimate soil erosion from such practices using a stochastic climate that is typical of the area. For each hillslope polygon under consideration for a management activity, we will determine the topography from the digital elevation model (DEM). The WEPP predictions will be used by the optimizer to estimate sediment delivery for each scenario considered, and to determine if a given set of treatments exceeds the Basin's acceptable water quality threshold (TRPA 2006).

MAGIS and LMS/ENVISION

LMS/ENVISION will be used for visualization of the selected treatments and their effects across the Lake Tahoe Basin. Fuel reduction and forest restoration treatments selected in the MAGIS solution for various time periods will be stored in a LMS readable format. LMS/ENVISION will then be used for landscape visualization and graphical

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[1] Heuristic optimizer in MAGIS is the optimization engine of the system that uses an iterative method to generate a large number of alternative solutions (e.g., fuels treatment schedules), evaluate the alternatives based on given objective function and constraints in an iterative way, and select the best solution among alternatives. Currently, the optimizer employs a simulated annealing and a heuristic network algorithm to efficiently produce near-optimal solutions (Chung et al. 2005).

and tabular summarization. The potential use of LMS for automatic stand projection for MAGIS will be also investigated in this project.

Develop a heuristic optimizer in MAGIS to schedule fuel treatments over time to minimize expected loss

We will modify the existing MAGIS heuristic optimizer to select best fuel treatment locations in time and space under given fuel reduction, forest restoration, water quality, and cost efficiency goals. Scheduling spatial and temporal fuel treatments involves a large amount of data and an enormous number of solution alternatives, and thus becomes a large combinatorial optimization problem. We will build on the current MAGIS heuristic solver (Chung et al. 2005) that employs the Simulated Annealing algorithm (Kirkpatrick et al. 1983) to optimize resource management schedules while considering the economics of management activities, resource constraints, and operational feasibility. From this, a new heuristic optimizer will be created for use in FMLTB to generate and evaluate alternative fuel management schedules using the steps described both below and in Figure 2.

The optimizer will begin with an initial solution that represents the current conditions with no additional treatments planned (the no action alternative). For subsequent iterations, the optimizer modifies the previous solution by randomly selecting a certain number of stands and altering the previously assigned treatment-timing combinations (for example, changing from no action during the planning horizon to thinning in the first period), creating a new solution. To evaluate the new solution, landscape files are updated using the FMLTB interfaces to read FVS-FFE data for the treatment locations, and FlamMap is run to compute grid-cell specific fire behavior data. FS WEPP is then run for the treatment locations to predict sediment loading from the treatment activities. In this step computations are done for only the modified part of the landscape to minimize solution time. Using the updated landscape, a fire growth simulator similar to Minimum Travel Time (MTT) in FlamMap (Finney 2002) will be used to predict fire spread and intensity on the landscape for the user-specified fire scenarios. The optimizer then evaluates the new solution in terms of changes in fire behavior across a landscape, and given forest restoration and water quality goals, as well as total treatment costs against given budget constraint. After a large number of iterations of the above procedure, the optimizer will select the best spatial and temporal arrangement of fuel treatments that produces the maximum treatment benefits over time while meeting given resource and operational constraints.

We propose to measure treatment benefits as the reduction in loss caused by potential future wildland fires. This is expected to spatially place treatments to reduce the likelihood of fire affecting locations where the potential loss to fire is greatest (e.g., WUI, commercial and residential areas, etc.). In this approach the objective function is set to minimize the total amount of loss that is expected to occur in one or more user-specified fire scenarios of concern (Ager et al. 2006). Each fire scenario contains a specific weather condition with an associated probability. After multiple fire scenarios are simulated by the FlamMap MTT logic, the expected loss will be calculated based on the probability of each fire scenario of concern, where fire is simulated to burn on the landscape, fire intensities, and the change in financial and ecological value that is expected to occur with various fire intensities (Figure 3). The location and average value of private structures will be included in these analyses (average house values will be used instead of individual values for social equity reasons) as well as the location and value of other types of infrastructure such as commercial structures, hospitals and other public structures, highways, and power lines. Net ecological change will be handled by classifying vegetation into strata and in consultation with managers, estimating the net change in value associated with fire of various intensities.

Evaluate fuel treatment alternatives for other forest management goals

FMLTB solutions can be evaluated in terms of their ability to promote or sustain species of special concern. By utilizing detailed compositional data derived from the Tahoe Basin Existing Vegetation Map (TBEVM - ://gforge.casil.ucdavis.edu/projects/tbevm), stand selection constraints can be developed to include, exclude, or weight stands that contain species of special concern. For example, continuous cover estimates of Aspen and conifer species derived from the TBEVM can be used to develop selection constraints that promote fuels reductions in encroached aspen stands (aspen and conifer with mixed cover estimates), or exclude thinning in pure aspen stands (Figure 4). The solutions will be also evaluated in terms of water quality goals, as well as cost effectiveness and road accessibility. The maximum allowed sediment delivery from treatments (TRPA 2006) will be set up through consultation with managers, and used as a constraint during optimization. Treating steeply sloped areas or areas with limited access are usually costly, but could provide large fire and ecological benefits. FMLTB will be designed to evaluate cost effectiveness of given fuel treatment alternatives by locations and methods. Among alternative solutions (fuel management schedules) evaluated, the solution that maintains the maximum positive effects on fire hazard reduction and ecosystem restoration over time and meets sediment delivery, budget, and operational constraints will be selected. With intelligent neighborhood search algorithms, the Simulated Annealing heuristic can efficiently evaluate a large number of alternative solutions and converge to a feasible solution in a reasonable computation time (Öhman and Eriksson 1998).

4.2 Develop applications for the Lake Tahoe Basin.

Working with forest managers in the Lake Tahoe Basin, we will develop spatially explicit fuel management schedules for the entire Basin for a 50-year planning horizon with five 10-year planning periods. We will present our results at a workshop with field managers to ensure that our results are useful to them. In the decision support system, the FVS-FFE will be used to address temporal effects of fuel treatments, assess longevity of treatments, and predict input data for FlamMap. Running FVS-FFE requires inventory data that reflects current vegetation for the area of interest. We will use the latest FIA inventory imputed to the vegetation polygons using the TBEVM. This work is being conducted by the Region 5 Remote Sensing Lab (Ramirez 2007). Several GIS layers will be required: stand or treatment unit boundaries and road networks for treatment scheduling, and elevation, slope, and aspect layers for FlamMap. We will use stand boundaries as treatment unit boundaries unless specified by field managers. Multiple stands will be grouped based on vegetation characteristics, topographic conditions and ownerships, and we will develop silvicultural/fuel treatment options applicable to each group of stands. Economic attributes associated with treatment methods, road networks, access points to treatment units and access costs will be identified.

Validating the accuracy of individual models employed in FMLTB relies on model developers and users, and is out of scope of this project. However, we will perform a sensitivity analysis involving alternative spatially-explicit fuel management schedules for different management objectives and constraint levels (e.g., forest restoration, sediment delivery, budget, etc.) to test FMLTB. This sensitivity analysis will offer not only an additional test of the system, but also a demonstration of how the system can be applied to provide land managers with knowledge of how to best spend funds to achieve specific fuel reduction, forest restoration, and water quality goals, and also a comparison of the cost-effectiveness of various levels of fuel treatments. We will also evaluate the system outputs in terms of the feasibility of implementation and the improvement in treatment benefits. The best spatial/temporal fuel treatment schedule results will be presented to land managers in the Basin to evaluate their applicability. To assess treatment benefits in changing fire behavior, the selected treatments will be compared with those developed solely from fire behavior standpoints (Finney 2002, Ager et al. 2006) or solely from economic standpoints (Zuuring et al. 1995, Chung et al. 2005). The effectiveness of the selected treatments in reducing sediment from potential future wildland fire will be also analyzed using GeoWEPP (Elliot 2004). The potential post-fire landscapes (one per period) based on the fires simulated in the final heuristic solver iteration will be modeled in GeoWEPP to predict stream channel sediment loading amounts from the treated landscape. Fires with the same start points and fire scenario conditions will be simulated in our system for the untreated (no action) landscape and the resulting sediment loading simulated in GeoWEPP. Comparison of predicted wildfire-induced sediment loading between the treated and untreated landscapes will indicate the effectiveness of the treatment schedule in reducing sediment in the Lake Tahoe basin.

4.3. Deliver FMLTB to end users.

We will deliver end products to managers and potential users in the Lake Tahoe Basin through meetings and workshops. End products include the stand-alone decision support system, user-manual, and documentation on the Tahoe application with the results of sensitivity analyses for various management strategies. We will interact with managers and system users on a regular basis during the project period to facilitate technology transfer of the system. We will also publish manuscripts and a technical report for the users in the Basin as well as for other land management agencies who are interested in using this decision support system. For other users, we will develop an interactive website for potential users to learn about the capabilities and requirements of the modeling system, an online interactive ‘getting started’ tutorial for users just starting to use the system, an online ‘smart’ tutorial and help system with animation that users can access directly from system screens to get targeted help precisely when it is needed, and user-friendly model documentation. These systems will be developed using HTML editors (Dreamweaver), sample data from test case(s), and any other applications needed for integrating animations and other visual aids.

5. Relationship of the research to previous relevant research, monitoring, and/or environmental improvement efforts

FMLTB will be built on the two on-going research projects previously described. While these current projects provide an overarching framework for FMLTB, we propose to carry out the following tasks in this proposed project to complete the development of FMLTB: 1) developing seamless data transfer interfaces between WEPP and MAGIS, and MAGIS and LMS/ENVISION, 2) modifying the existing heuristic optimizer to handle additional water quality and ecosystem restoration goals, 3) developing complete data sets and applications for the Basin, and 4) conducting technology transfer. In addition, two on-going SNPLMA Round 7 research projects conducted by the PI and Co-PI of this project will provide climate and soil data, and calibrated soil parameters required to run FS WEPP for the system applications in the Basin (Project numbers: #2A11 (PI: Brooks and Elliot) and #5B1 (PI: Foltz, Elliot, and Chung)). Further, we will leverage another work being funded by SNPLMA Round 7 research funds aimed at characterizing fire regimes and fuel characteristics of SEZs within the basin (PI: North).

This proposal also leverages research conducted by a Co-PI of this project in the development of the Tahoe Basin Existing Vegetation Map (TBEVM). The TBEVM, funded by Tahoe Regional Planning Agency, is a species-level map of vegetation composition and structure developed using high resolution satellite imagery (IKONOS) and species prediction modeling (Dobrowski et al. 2006, Greenberg et al. 2006). It is currently being used to impute forest inventory and analysis (FIA) data to stand polygons within the basin (Carlos Ramirez Remote Sensing Project Leader, USFS Remote Sensing Lab; personal communication). The TBEVM will provide the basis for a number of core project needs including stand delineations, stand composition and structural information. Additionally, biophysical, climatic, and edaphic spatial datasets used in the development of the TBEVM, will also be available as inputs for FlamMap, FVS-FFE, and FS WEPP. Available datasets include: 1) slope, aspect, and hillslope delineations derived from a DEM, 2) soil texture and rock content derived from SSURGO data, 3) vegetation cover estimates derived from TBEVM, and 4) weather data derived from long term meteorological stations.

6. Strategy for Engaging with Managers

Interaction with LTBMU and other land management agencies in the Lake Tahoe Basin is envisioned throughout the process. Initially land managers and staff will be consulted for feedback on the conceptual model of FMLTB, including system interfaces and capabilities. This step helps ensure FMLTB addresses the important issues of concern and is designed with the user in mind. We will also consult with managers regarding the types of fuel treatments to analyze and the related costs. Volumes of various types of woody materials removed by mechanical treatments will be estimated via FVS using plot data, and the results verified by managers. Managers will provide the objectives and limitations for the landscape fuel treatment alternatives to be developed and evaluated. This includes the viable number of acres to treat by period and/or treatment budgets, thresholds and limitations to mitigate the effects on resources adversely affected by fuel treatment activities (e.g., sedimentation resulting from fuel treatments) and the fire scenarios of concern to analyze. We envision a series of system solutions to develop the landscape-scale fuel treatment alternatives. Manager interaction is critical in this process to develop viable alternatives from the many possible perspectives. Managers will be also consulted for the most useful formats for "final" product/information dissemination (e.g., creating new tools and functions in the decision support system). To deliver the final products, we will conduct a workshop with managers and potential end users. During the workshop, we will present the decision support system, its applications, limitations, and analysis results of different management strategies for the Lake Tahoe Basin.

7. Deliverables/Products

Five products/deliverables will result from this project:

1) Decision support system installation DVD/CD that potential end users could readily access and use to install the system on local computers, as well as web-based distribution and user support materials.
2) A series of PowerPoint presentations and a manual that describe data requirements and how to use the system and develop applications.
3) Quarterly reports that describe the progress and expenditure of the project
4) Two manuscripts suitable for publication in a peer-reviewed journal that describe the system and applications.
5) One synthesis report suitable for publication as a Forest Service Technical Report that describes the system, the Lake Tahoe applications, and tradeoff analyses of different fuel management strategies for the Lake Tahoe Basin.

III. Schedule of Milestones/Deliverables

This project will require 2.5 years starting from June 2009 and ending December 2011.

- June. 2009 ~ Sep. 2010: Completing the development of data transfer interfaces between models
- Oct. 2010 ~ Dec. 2011: Developing applications in the Lake Tahoe Basin, system delivery, and publications

Table 1. Schedules of deliverables/products

Milestones/Deliverable	Description	Schedules
Quarterly report	Progress report	Sep. 2009
Data transfer interfaces among the existing models	Interface that facilitates automatic data transfers between MAGIS, FlamMap, FVS-FFE, and FS WEPP	Dec. 2009
Quarterly report	Progress report describing data transfer interfaces	Dec. 2009
Heuristic optimizer	Optimizer that integrates resource issues/economics with fire behavior projections for various treatment options	Mar. 2010
Quarterly report	Progress report describing heuristic optimizer	Mar. 2010
Quarterly report	Progress report describing linkage between MAGIS and LMS/ENVISION	June 2010
Data transfer interface between MAGIS and LMS	Decision support system that integrates MAGIS and LMS/ENVISION for enhanced solution display	Sep. 2010
Quarterly report	Progress report describing the integrated support system	Sep. 2010
Data collection	Input data collected for the support system	Dec. 2010
Quarterly report	Progress report describing data collection	Dec. 2010
Lake Tahoe model	Application built from real data for testing, with input from local management for resource objectives and constraints	Mar. 2011
Quarterly report	Progress report describing the Lake Tahoe application	Mar. 2011
Workshop	We will present our results at a workshop with field managers to ensure that our results are useful to them	Jun. 2011
Quarterly report	Progress report describing the analysis results	June 2011
Publication	Peer-reviewed journal manuscript describing the support system and its applications	Sep. 2011
Presentations	Present results at professional conferences	Sep. 2011
Applications report	Document on DSS and its applications in two national forests	Sep. 2011
Quarterly report	Progress report describing the summary of applications	Sep. 2011
DSS Technology transfer	Initial draft of Website and User Documentation with active tutorials.	Oct. 2011
DSS Distribution System	Installation package and software delivery system (ftp and website for downloads and updates)	Nov. 2011
System manual	Document describing how to use the support system	Nov. 2011
Workshop	We will hold a workshop for demonstrating and teaching the new modeling system to potential users	Nov. 2011
DSS Technology transfer	Final Drafts of Website and User Documentation with active tutorials	Nov. 2011
DSS Distribution System	Installation package and software delivery system (ftp and website for downloads and updates)	Nov. 2011
Publication	Peer-reviewed journal manuscript describing tradeoffs of different fuels management strategies in the Lake Tahoe Basin	Dec. 2011
Forest Service technical report	Synthesis report describing the support system, applications, and analysis results	Dec. 2011
Final Report	Submission of the final report to the PSW Research Station	Dec. 2011

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V. Figures

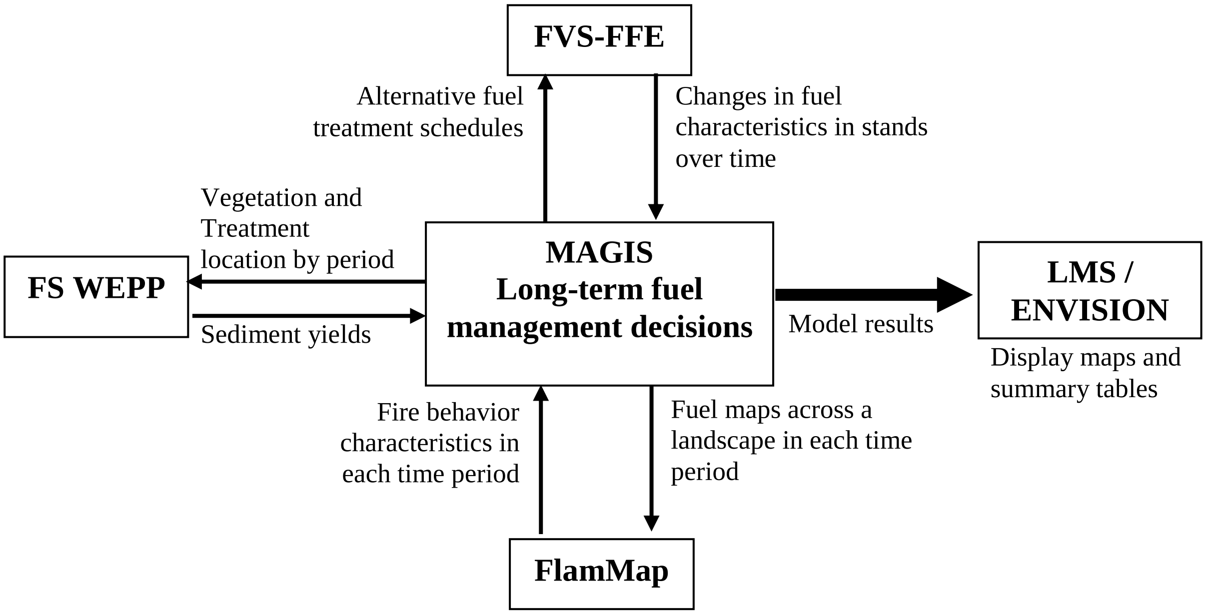


Figure 1. Data transfers among MAGIS, FVS-FFE, FlamMap, FS WEPP, and LMS/ENVISION.

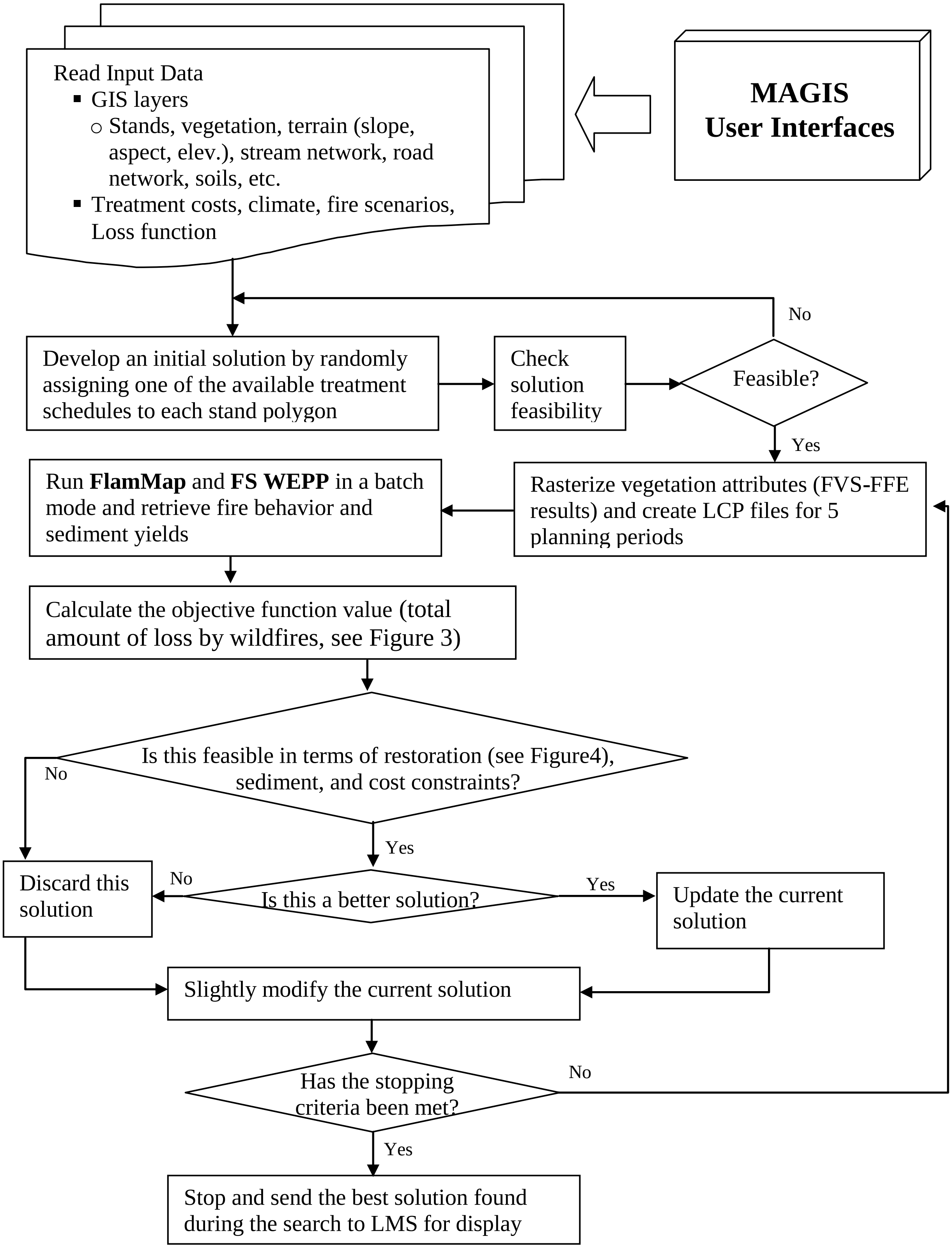
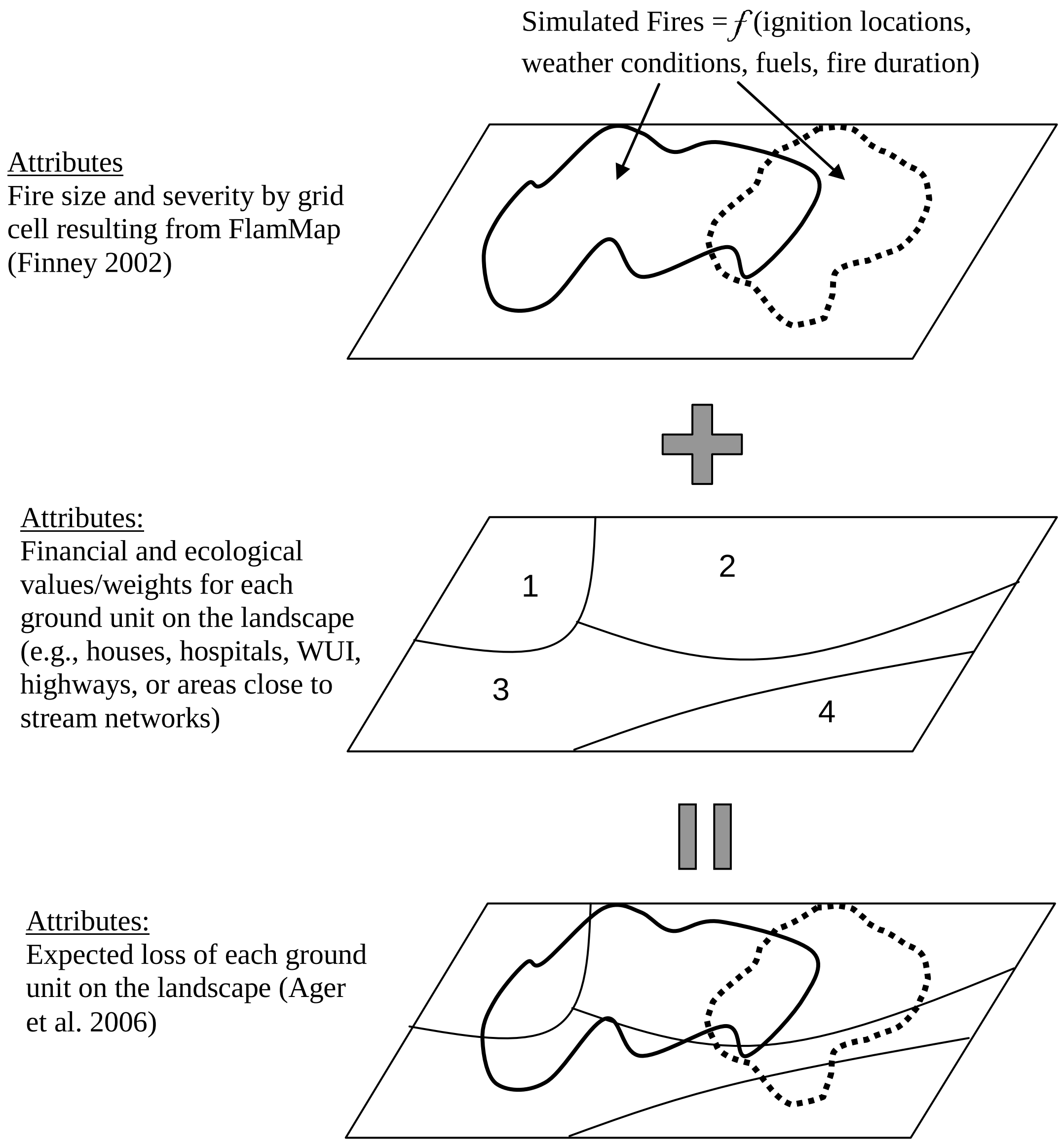


Figure 2. Proposed structure of the heuristic optimizer (Chung et al. 2005).



Objective Function

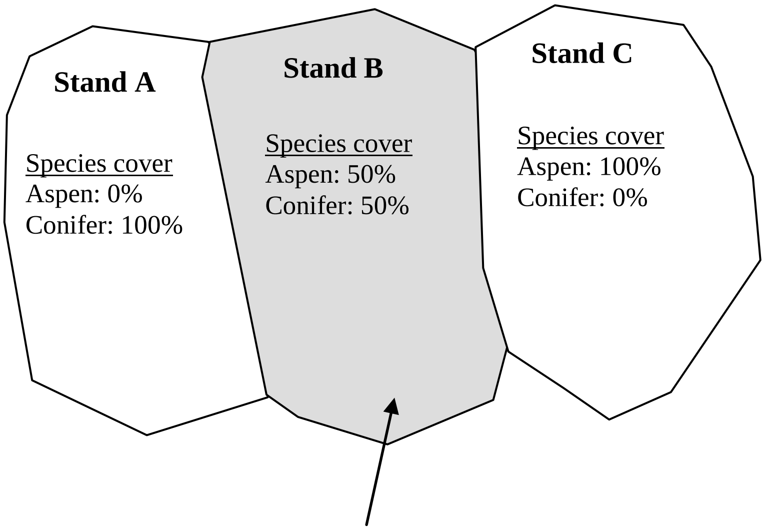
Minimize Total Expected Loss across the Lake Tahoe Basin

where,

$$\text{Total Expected Loss} = \sum_{i=1}^{N} \text{Total loss from simulated fires under Fire Scenario}_i \times \text{Likelihood of Fire Scenario}_i$$

N = Number of fire scenarios analyzed

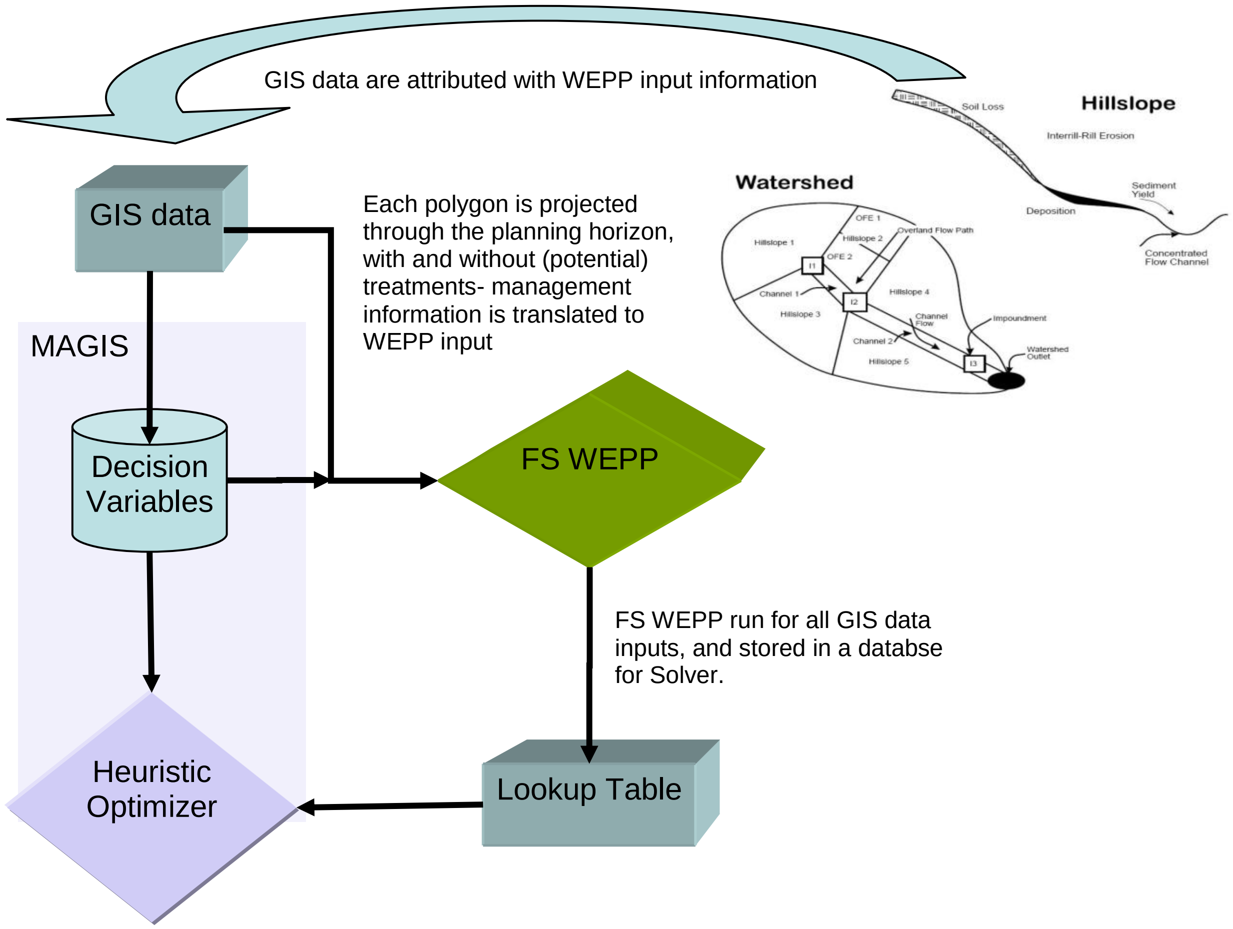
Figure 3. Conceptual approach to calculating total expected loss from various fire scenarios (ignition locations, weather conditions, and fire duration). We will use the existing fire and weather history data in the Basin (Murphy and Knopp 2000) and consult with managers to determine various fire scenarios and their likelihood of occurrence.



Stand B can be prioritized for fuels treatment by the following constraint set in the heuristic optimizer.

Constraint
Σ Acres to be treated where Aspen species can be most promoted ≥ Minimum acre requirement

Figure 4. Conceptual approach to promoting desirable tree species and vegetation structure in the Lake Tahoe Basin using the heuristic optimizer. For example, species cover data from the TBEVM (Dobrowski et al. 2006) can be used in prioritizing stands for treatment to promote Aspen species in the Lake Tahoe Basin, while simultaneously addressing treatment effects on fire behavior and water quality.



Each polygon is projected through the planning horizon, with and without (potential) treatments- management information is translated to WEPP input

FS WEPP run for all GIS data inputs, and stored in a databse for Solver.

Constraint

Σ Total amount of sediment delivery per watershed ≥ Minimum threshold per watershed

Figure 5. Linkage between FS WEPP and MAGIS. FS WEPP will be used to estimate the effects of fuels treatments on sediment delivery. Using these sediment delivery estimates, the heuristic optimizer will select treatment locations so that the total sediment delivery does not exceed the maximum threshold per watershed (TRPA 2006), while simultaneously addressing treatment effects on fuel reduction and forest restoration goals.