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Software for Calculating Vegetation Disturbance and Recovery by Using the Equivalent Clearcut Area Model

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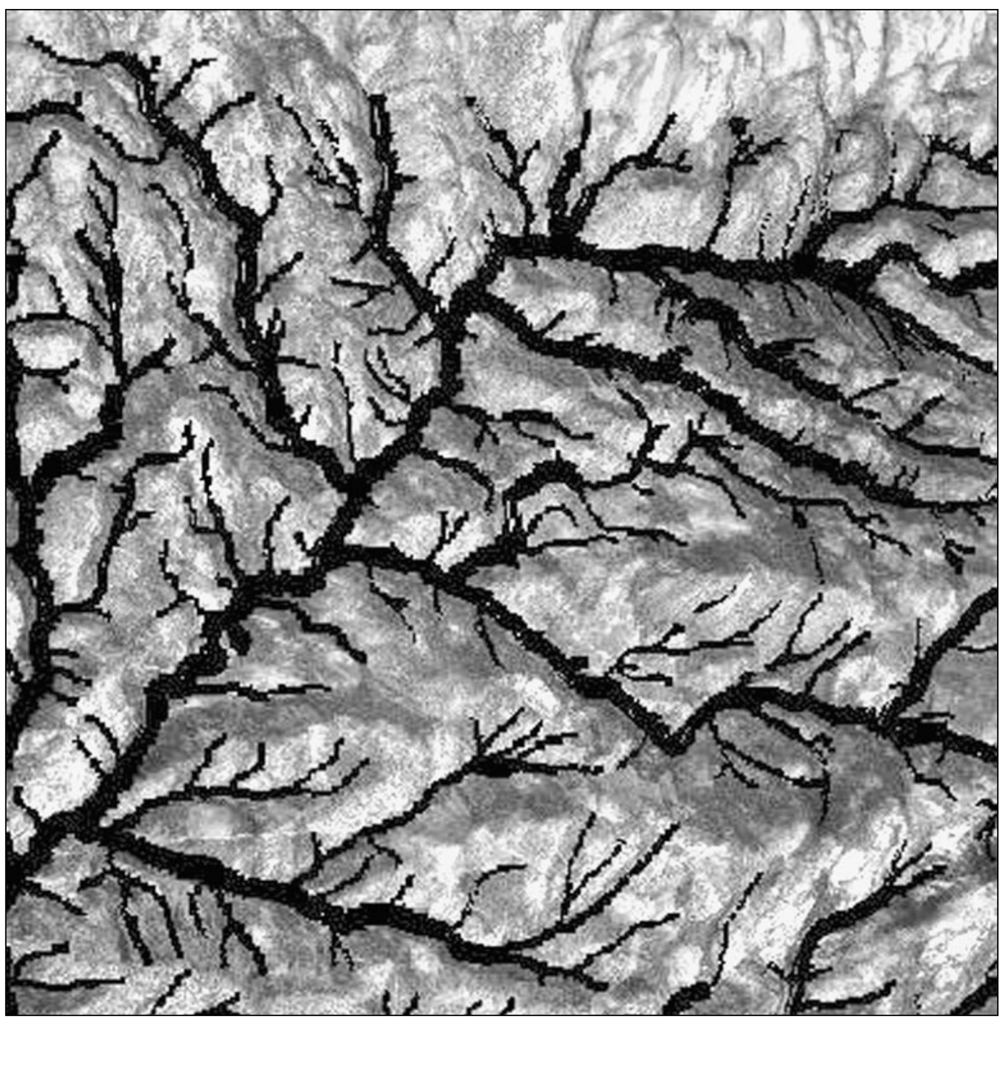

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Abstract

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The use of cumulative watershed effects models is mandated as part of interagency consultation over projects that might affect habitat for salmonids federally listed as threatened or endangered. Cumulative effects analysis is also required by a number of national forest plans in the Pacific Northwest Region (Region 6). Cumulative watershed effects in many cases are measured with the equivalent clearcut area (ECA) model, which generates an index of cumulative disturbance by considering disturbance type, extent, and recovery over time. Although the model has many limitations, it provides an index of vegetative disturbance that can be used to compare the existing condition of different watersheds, and the potential impacts among land management alternatives. Calculating ECA on multiple watersheds and management scenarios for project-level analysis is a tedious process. We automated the process with a program called Equivalent Treatment Area Calculator to streamline its application on national forests in the Blue Mountains of eastern Oregon. The program, operation, and limitations of the ECA model are described in this paper.

Keywords: ECA, equivalent clearcut area, cumulative watershed effects, equivalent roaded area.

Introduction

Understanding and modeling the cumulative watershed effects of management and natural disturbance is a significant challenge for land managers (U.S. Council on Environmental Quality 1997). Cumulative watershed effects can result from minor actions taking place over a period of time that collectively are thought to alter hydrologic response (FEMAT 1993). A wide variety of qualitative and quantitative methods for analyzing cumulative watershed effects have been developed over the past 25 to 30 years (Berg et al. 1996, Reid 1993). One of the earliest quantitative approaches used by the Forest Service was the equivalent clearcut area (ECA) method, which accounts for past and future effects of different types of disturbances by standardizing the effects and modeling the recovery over time. It was originally developed for use in northern Idaho and Montana (King 1989, USDA FS 1974) where it was used to measure the potential impacts of alternative timber harvesting schedules. A more encompassing model, equivalent roaded area (ERA), was later developed in the Pacific Southwest Region by using the same framework, and was extensively used in the Sierra Nevada Ecosystem Project (Menning et al. 1997).

Both models assume a direct linkage between vegetation disturbance and hydrologic response (i.e., peak flows and water yield) (Bosch and Hewlett 1982, Stednick 1996). Despite conficting literature on the existence of these linkages and other limitations (Beschta et al. 2000, Menning et al. 1997), the model is still required for consultation with the National Oceanic and Atmospheric Administration (NOAA) Fisheries Department and the U.S. Fish and Wildlife Service (USDC NMFS 1995, USDI FWS 1998) for all proposed management actions in the Blue Mountains national forests and elsewhere within the range covered by PACFISH (USDA USDI 1995a) and INFISH (USDA USDI 1995b) policies. An ECA analysis is typically applied at the subwatershed scale (10,000 to 40,000 acres) as part of analyzing alternative management actions developed in the National Environmental Policy Act (NEPA) project analysis. Equivalent clearcut area measures are also relevant to standards and guidelines for many of the current national forest plans that specify maximum treatment acreages on a subwatershed basis over time. For the Umatilla National Forest, there is no explicit ECA standard in the forest plan, but an ECA of 15 percent is used as a surrogate for a forest plan standard that allows a maximum of 30 percent of the forested area in a subwatershed to be in the 0 to 10-year age class.

The ECA model uses one set of coefficients to describe the proportion of the total basal area removed for different disturbance types, including harvest prescriptions, wildfire, prescribed fire, roads, and insect mortality. A second set determines how fast the treated acres recover to 100 percent of potential leaf area or canopy closure, at which point the acre is assumed to have hydrologic function the same as an untreated acre. The physical model behind ECA as a cumulative-effects measure is that vegetation removal changes water yield characteristics (peak flow, timing, total yield) in rough proportion to leaf area, or basal area removed from a site. Several studies have shown that timber harvest affects water yield by reducing water loss associated with interception and evapotranspiration, or by changing snow distribution and melt rates (Hicks et al. 1991, Scherer 2001, Stednick 1996). The hydrologic changes may lead to destabilized stream channels and other adverse ecological effects (Reid 1993). The ECA statistic (percentage of area in equivalent clearcut condition) is typically used in conjunction with climatic data to evaluate the cumulative effects of vegetative removal on water yields and peak flows. The ECA statistic also may be used as a general guide to overall watershed condition when coupled with site-specific evaluations.

Calculation of the ECA statistic can be a time-consuming process for watersheds that have received multiple disturbances over time. Calculations are complicated by the consideration of multiple treatment alternatives and revision of treatment intensities in the process of project development. This paper describes the program Equivalent Treatment Area Calculator (ETAC) that vastly simplifies calculation of the ECA statistic. The ETAC program is intended to provide a consistent approach to measuring harvest and other impacts to forest vegetation. This paper describes the most recent version of the program, methods for preparing data, considerations for use of the model, and includes an example analysis.

ETAC Software

Program Overview and Requirements

The ETAC program evolved from prototype software developed in 1994 by the authors and has been in continual use on the Umatilla National Forest for analyzing ECA on a number of forest management projects. The program evolved with each application, resulting in the current version that offers a relatively streamlined process for calculating the ECA statistic. The current software and example data are available from http://www.fs.fed.us/r6/uma/ager.

The ETAC was developed in object Pascal as implemented in Borland Delphi 6[1] (Borland Software Corporation, Scotts Valley, CA). Database connectivity was encapsulated into the program by using Microsoft ActiveX Data objects (ADO) version 2.5. Key features of the program include the ability to process a large

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or services.

number of spatial units (e.g., subwatersheds) and alternative management scenarios from a single database. Each combination of alternative and subwatershed is evaluated individually and written as one record to the output database.

The ETAC requires about 2 MB of random access memory (RAM). The application requires the installation of ADO 2.1 or later on the client computer. The ADO and OLE DB are part of the Microsoft Data Access Control components supplied by Microsoft and installed with Windows 98 and later Windows versions.

Program Operation

The program interface accepts entries for the input and output databases, and the number of years to evaluate. The input database must be a valid Microsoft ACCESS database, and the data must be contained within a table named ETARUN within the database. An example input database (ETAC.MDB) is provided with the program. The required field names and field formats for the database are shown in table 1.

Table 1—Required fields and format for the Equivalent Treatment Area Calculator input database

Field name	Format	Explanation
Alternative	Integer from 1 to 10	Harvest alternative
Year cut	Integer	Year of past or proposed treatment
SWS	Alpha, up to 10 characters	Subwatershed (HUC 6) of past or proposed harvest
Acres cut	Real	The number of acres harvested
Forested acres	Real	The total acres that could potentially support forest vegetation in the subwatershed
ECA	Real	The equivalent treatment coefficient associated with the treatment

HUC 6 = sixth-order hydrologic unit code.

The order of the fields within the database is not important. Any additional fields in the input database are ignored by the program. The output database is specified without an extension. In addition to input and output databases, the user specifies the starting year for the evaluation and the number of years to calculate ECA. The run is commenced with the Run button. The output database contains fields for the subwatershed, project alternative label, the total ECA acres, and the ECA statistic for each alternative by subwatershed (SWS) combination (table 2).

Table 2—Fields and format of the output database for the Equivalent Treatment Area Calculator (ETAC) program

Field name	Format	Explanation
Alternative	Integer from 1 to 10	Harvest alternative
Year	Integer	Year of past or proposed treatment
SWS	Alpha, 1 to 12 characters	Subwatershed code
ECA acres	Real	The sum of the equivalent treatment acres for the alternative by SWS combination
Forested acres	Real	The total acres that potentially could grow trees in the subwatershed. These data are copied from the input database
ECA	Real	Percentage of forested acres in the subwatershed in equivalent clearcut condition

Note: ETAC outputs one record for each combination of project alternative and subwatershed.

Preparation of the Input Database

An example input database is provided with the program (ETAC.MDB) to illustrate formats and data conventions. The database does not need to be sorted, and additional fields beyond those shown in table 1 can be included. However, the field names for fields in table 1 must be exactly as shown. Input databases are built in a multiple-step process that begins with geographic information system (GIS) operations to determine acres harvested by year, subwatershed, harvest prescription, and potential vegetation group. The exact sequence of events for completing these calculations depends on the GIS formats, and thus can only be described in general. Typically, the relevant GIS layers (i.e., all past and proposed harvest activity layers by SWS) are processed with a UNION operation in ArcGIS, and the attribute table is exported to a database that contains the year and prescription for all past and proposed treatment areas. A relational query between this database table and one containing the ECA coefficients and recovery rates (ETAC_COEFF table in ETAC.MDB) is then performed. Field names may need to be changed to match those required by the program. Total forested subwatershed acreage is added to the database by a similar relational query of the appropriate vegetation database. Forested acres represent the total acres potentially forested as determined from the potential vegetation layer.

The ECA treatment coefficients are intended to approximate the proportion of the basal area removed from a stand for each prescription type, and recovery rates are specific for each potential vegetation group. Local specialists (Johnson and Mrowka 1993) originally developed the draft coefficients for the Umatilla National Forest (table 3), which are being continually refined and adjusted to reflect current information. Note that for each plant group there are only three possible recovery

Table 3—Equivalent treatment area coefficients by prescription type

Prescription code	Description	Equivalent treatment area coefficient
HCPH	Regeneration harvest, clearcut, patch	1.0
HCSP	Regeneration harvest, clearcut, strip	1.0
HCSD	Regeneration harvest, clearcut, stand	1.0
HPSW	Regeneration harvest, prep cut, three-stage shelterwood	.6
HSSW	Regeneration harvest, seed cut, three-stage shelterwood	.2
HSSW	Regeneration harvest, combined seed/prep cut, two-stage shelterwood	.8
HRSW	Regeneration harvest, removal cut, two- or three-stage shelterwood	.2
HPST	Regeneration harvest, prep cut, three-stage seed tree	.6
HSST	Regeneration harvest, seed cut, three-stage seed tree	.3
HSST	Regeneration harvest, combined seed/prep cut, two-stage seed tree	.9
HRST	Regeneration harvest, removal cut, two- or three-stage seed tree	.1
HROS	Regeneration harvest, removal cut, seed tree	.1
HSEI	Regeneration harvest, select cut, individual tree	.3
HSEG	Regeneration harvest, select cut, group	1.0
HPRC	Regeneration harvest, partial removal	.3
HIIM	Intermediate harvest methods, improvements	.25
HITH	Intermediate harvest method, thin	.3
HISM	Intermediate harvest method, lodgepole salvage	1.0
HISS	Intermediate harvest method, sanitation	Proportion of basal area removed
HISM	Intermediate harvest method, mortality salvage	

rates, the fastest for thinning-type prescriptions, the slowest for regeneration harvests, and an intermediate recovery rate for shelterwood/seed tree cuts (table 4). Often project specialists modify these coefficients to meet site-specific conditions. Coefficients for prescriptions that involve salvage, prescribed fire, and other irregular treatments need to be derived specifically for each project. Professional judgment is required in some instances to assign ECA coefficients to particular prescriptions, especially ones that involve uneven harvesting (e.g., salvage).

Table 4—Recovery coefficients and years to recover by prescription group and potential vegetation group

		Plant association					
		Moist forest		Cold forest		Dry forest	
Prescription	Equivalent treatment area coefficient	Recovery coefficient	Years to recovery	Recovery coefficient	Years to recovery	Recovery coefficient	Years to recovery
		%/Year		*%/Year*		*%/Year*	
Regeneration harvest (clearcut or heavy salvage)	1.0	4.3	23	3.0	30	3.0	33
Seed tree/ shelter prep	.6 to .9	5.3	19	3.6	26	3.6	28
Thinnings, partials, select cuts	<.6	8.3	12	4.4	18	4.4	22

Consideration of Roads in the ETAC Model

Roads both within and outside of harvest units may be included in ECA calculations. Typically, roads are given an ECA coefficient of 1.0 and a recovery rate of 0, although other approaches have been used (Menning et al. 1997). The area of roads is best determined by querying the transportation layer for the total length in each subwatershed and assuming an average width. Roads are in some ways functionally clearcut areas, although more compacted, so infiltration is reduced and runoff rates may be more accelerated than in a true clearcut. There has been considerable discussion about the role of roads in ECA calculations. If roads are omitted from the calculations, the rationale should be documented.

Discussion

The ECA statistic encapsulates the history of vegetative disturbance within a watershed and can provide a broad indicator of the potential for change in water yields and peak streamflow from forest management activities. However, ECA is one of many measures of watershed health and is not directly predictive of increased peak flows or impacts to streams. The ECA procedure has had many criticisms owing to inadequate explanation of the ECA analysis in environmental documentation, lack of a standard procedure for its calculation, and lack of interpretation using collateral data. A consistent relationship between the ECA statistic and hydrologic variables (peak flows and water yields) has not been established (Beschta et al. 2000, Scherer 2001). Typically, the ECA statistic for a given subwatershed is compared with an established ECA threshold (15 percent in the biological opinions in USDC NMFS 1995, and USDI FWS 1998). Supporting information from other indicators of watershed health is useful to interpreting ECA results and predicting the likelihood of adverse effects.

In terms of the application of the ECA procedure on the Blue Mountains national forests in eastern Oregon, we have identified a number of additional limitations and suggestions for appropriate uses, as described below:

The original ECA method was developed in north Idaho and Montana where spring snowmelt runoff is the dominant mechanism generating streamflow. In areas like the Blue Mountains of eastern Oregon, streamflow is generated from multiple hydrologic processes including spring snowmelt and winter rain on snow. Variable climate (maritime and continental), geology, and disturbance (fire, floods, wind) also exert strong influences on water yields and peak flows.

Using one ECA threshold (15 percent), as required in the 1995 and 1998 biological opinions (USDC NMFS 1995, USDF FWS 1998) ignores the variability among subwatersheds in their vegetative disturbance cycles. Thus each subwatershed has a background level of vegetative disturbance that, over time, contributes to a background ECA.

The ECA measure as currently applied is calculated based on forested land rather than the total area within a watershed. Forest management in watersheds that are only partially forested is highly constrained by ECA, even though the overall hydrologic condition of a watershed with a relatively small amount of forest is more closely related to the condition of the nonforest lands, and other disturbances like grazing may be a more significant influence on watershed health.

At present, there are limited data on the recovery rates of herbaceous and shrub vegetation, which can rapidly restore some of the hydrological/soil problems caused by harvesting activities, such as erosion and sedimentation. Future development of the ECA model should consider these vegetation types as well.

The ECA model is best used in conjunction with other relevant data to further assess potential for changes in water yield and peak flows, and impacts to stream channels and riparian areas. Specifically, climatic and streamflow data from nearby stations should be examined to characterize streamflow-generating mechanisms, including timing and volume of runoff, and stream survey data should be evaluated to assess channel stability.

Mixed ownership and the lack of vegetation information on non-Forest Service lands make it impractical to accurately measure ECA for all lands within many watersheds.

Example Analysis

The example analysis is from the Pedro/Colt Timber Sale and Fire Reintroduction Project on the Walla Walla Ranger District, Umatilla National Forest. This project is located in the Upper Grande Ronde subbasin and considers four management alternatives within five subwatersheds. Thus ECA measures are required through time for the 20 combinations of subwatersheds and management alternatives. The proposed management uses a landscape approach to restore ecosystem functions on about 9,200 acres by using prescribed fire and timber harvest. Timber harvest is proposed to reduce stocking levels and modify the fuel structure prior to igniting prescribed fire on about 10,560 acres. Harvest is focused in stands with structural components that deviate from historical fire regimes and that are at risk for catastrophic damage. Silvicultural prescriptions include shelterwood, seed-tree cuts, thinning, and improvement harvest. Landscape-scale prescribed fire, by both aerial and on-the-ground ignition, would occur on about 7,800 acres. Some stands may

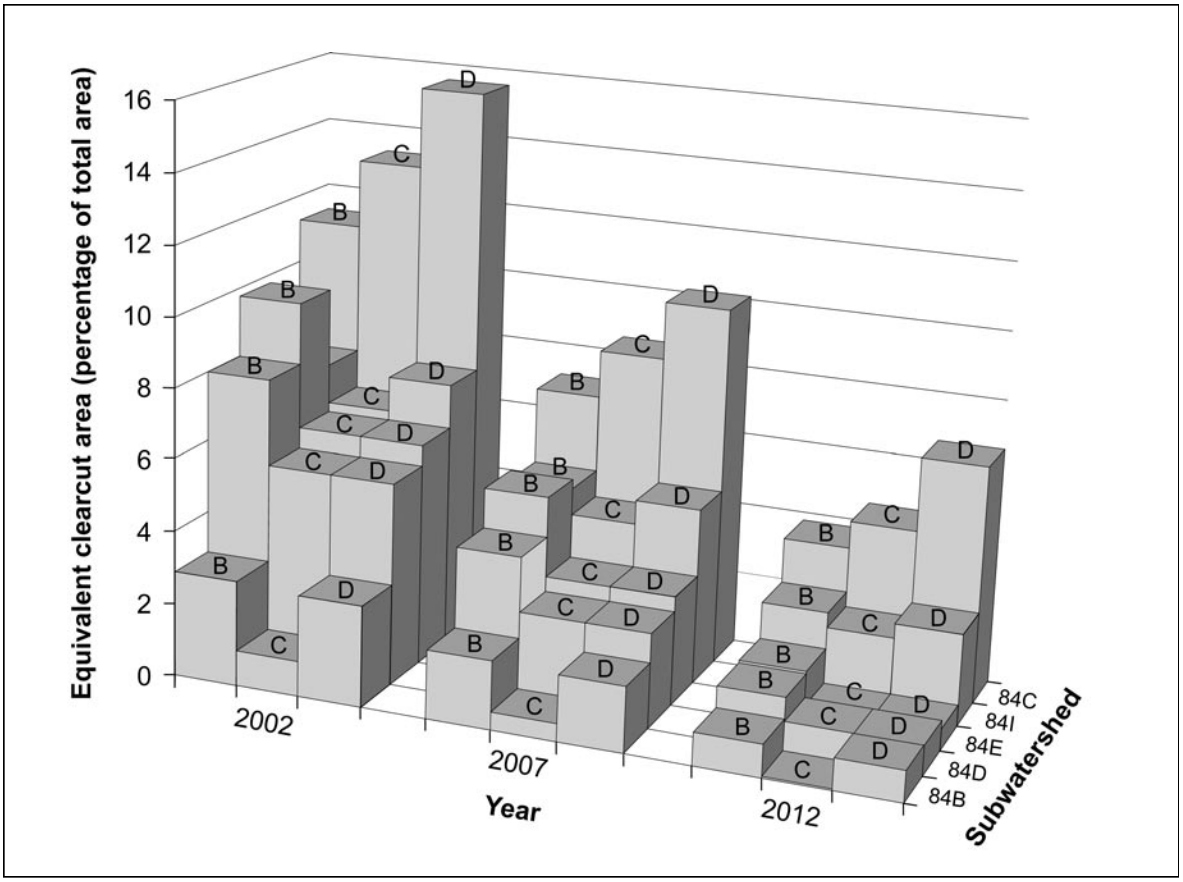

Figure 1—Results of the equivalent clearcut area (ECA) analysis for the Pedro/Colt timber sale, Walla Walla Ranger District, Umatilla National Forest. Chart shows the ECA levels by subwatershed and project alternative through time. Alternatives B, C, and D are different management alternatives for thinning and underburning forest stands within the Pedro/Colt project area.

take multiple ignitions to reach the desired fuel composition. The landscape treatments would occur over a 10- to 15-year period.

The example database for this area is the ETACRUN table in the ETAC.MDB database. Fields are present for management alternatives, total forested acres, acres cut, and ECA coefficients. The results of running these data through ETAC (fig. 1) show large differences in ECA among the subwatersheds for both existing and future conditions. Clearly, subwatershed 84C, and to a lesser extent 84E and 84I, have relatively high ECA percentages, although only alternative D in subwatershed 84C exceeds the 15 percent threshold. Watershed 84C maintains a relatively high ECA percentage into the future, whereas most of the others show minor residual effects from management activities. Note that the no-action alternative (A) projects a 0 percent ECA into the future; thus the program does not predict risks from (assumes no chance of) natural disturbances (wildfire, insect outbreaks).

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Metric Equivalents

1 acre = 0.405 hectares

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