Characterizing Impacts of and Recovery from Surface Coal Mining in Appalachian Forested Landscapes Using Landsat Imagery

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ABSTRACT

This dissertation describes research investigating the potential for using Landsat data to identify and characterize woody canopy cover on reclaimed coal-mined lands through three separate studies. The objective of the first study was to assess whether surface coal mines in the forested central Appalachian regions of the US can be separated from the other prevalent forest-replacing disturbances through analysis of an interannual chronosequence of Landsat images. Disturbances were classified using descriptors of the disturbance/recovery trajectories: disturbance minimum, recovery slope and recovery maximum. Three vegetation indices (VIs) (normalized difference vegetation index, NDVI; tasseled cap greenness/brightness ratio, TC G/B; and inverse of Landsat band 3, B3I) were used to analyze multitemporal trajectories generated using both pixels and objects. Classification accuracies using objects were better than those obtained using pixels for all VIs. The highest object-based classification accuracy was achieved using TC G/B (89%), followed by NDVI (88%) and B3I (80%). The objective of the second study was to evaluate performance of a woody canopy cover (including both native and invasive species) estimation method based on the 2011 National Land Cover Database (NLCD) protocol for both mined and non-mined areas of the central Appalachians. Potential explanatory variables included raw and derived bands from leaf-on and leaf-off Landsat scenes plus terrain descriptors. Results show that the model developed to estimate canopy cover for mines (R^2 = 0.78, Adj. R^2 = 0.77, RMSE = 16%) is more robust than the models developed for non-mines, mixed, and all areas combined. The objective of the third study was to determine whether four disturbance/recovery parameters (recovery time, disturbance minimum, recovery slope, and recovery maximum), alone or in combination with variables identified in the second study, enable robust estimation of woody canopy cover on reclaimed surface coal mines. Of the disturbance/recovery parameters, only recovery time made a significant contribution to the model (R^2 0.45, Adj. R^2 0.44, RMSE 14%). Addition of leaf-on and leaf-off NDVI improved the R^2 to 0.54 (Adj. R^2 0.53, RMSE 13%).

Analysis of Landsat data has strong potential for identifying reclaimed mines and characterizing the extent to which woody canopy has recovered post-reclamation.

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Chapter 1 Introduction

Coal mining creates a vast and significantly disturbed land base in the Appalachian coalfield. It is in the public interest that these disturbed lands be restored to environmentally sound conditions and productive uses. Reclamation in the post mining phase can help to restore the ecological functionality by enhancing environmental quality, reducing soil erosion, sequestering carbon and stimulating the forest succession process. It can result in commercial benefits such as production of the woody biomass for potential use in bioenergy feedstock and other traditional forest products (Burger et al, 2005). Prompt establishment of vegetation after mining was mandated by The Surface Mining Control and Reclamation Act (SMCRA) of 1977. This US federal law established a nationwide program to protect the society and environment from the adverse effects of coal mining. The Environmental Protection Performance Standard in this law required "restoration of land affected to a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses which there is reasonable likelihood of" (SMCRA 1977). As a result, most areas mined after 1977 were reclaimed with vegetative covers that qualified the federal standards but often failed to return productivity to the ecosystem (Angel et al. 2005). Most areas were reclaimed with herbaceous species, transforming pre-mined forests to unproductive grasslands (Burger 2005). The aggressive grasses and invasive woody species hindered the establishment of native tree species. Such reclaimed areas are in various states of arrested succession, where it would take long time periods to regain the forested states comparable to native forests if left to natural succession (Groninger 2007). A strong need was realized to improve the productivity of these under-utilized lands by replacing traditional reclamation practices with Forestry Reclamation Approaches (FRA) (Burger 2005). Beginning in 2005, the Office of Surface Mining Appalachian Regional Reforestation Initiative (ARRI) was established to promote reforestations in the reclaimed mined lands to accelerate the pace of forest succession (Angel 2005). Replacement of current vegetation with productive forest systems, either native non-managed forest or plantations intended to produce high-volume woody species for harvest as biomass, has the potential to create substantial economic benefits for landowners and additional ecological benefits for the society (Fields-Johnson et al. 2008).

Approximately 600,000 hectares have been mined and reclaimed under the SMCRA in eastern U.S alone (Zipper 2007). Knowledge of the extent of such reclaimed mines, their current uses and vegetation developmental stage is critical to managing them. However, very little information is available about this land resource from the publically accessible database. The currently available mined lands database has insufficient information on the extent of lands reclaimed with traditional reclamation practices (practices before the FRA), their current uses, vegetative status and their capability to serve as renewable natural resource. There is no unified inventory of mined and reclaimed database that can be publically accessed and used in a geospatial application. Spatial data is necessary for locating the reclaimed mined lands and characterizing their vegetation status on a broad spatial scale. The absence of this fundamental knowledge about reclaimed coal mines has provoked the need for this study where remote sensing data and techniques are being used to identify and characterize reclaimed coal mined lands.

This study explores the feasibility of using multispectral and multitemporal Landsat images to identify coal-mined lands and to assess the post mining vegetation on the reclaimed surface coal mined lands in the southwestern Virginia. Remote sensing techniques are well suited to this job since they can be applied over large spatial extents, and in much more time and cost effective way than traditional field surveys (Cohen and Goward 2004). Other advantages of remote sensing techniques over field surveys include the capability to study progressive land cover changes over extended time periods so as to define temporal trends, as well as the capability to assess mined areas without requiring property access permissions. Data from the Landsat suite of sensors offer several advantages which makes it the data of choice for this study. It has an unmatched archive of historical images that can be easily accessed and used to study historical disturbance events. Its spatial resolution of 30 m matches the grain size for most land management activities; for mined areas this resolution is optimal. It’s temporal and spectral resolution allow detailed analyses of the vegetative characteristics, for disturbance detection and recovery characterization. The recent no-cost distribution has facilitated the construction of a dense stack of interannual images to study the vegetation dynamics in the reclaimed mines. This study will generate valuable information about the extent of reclaimed mined lands, their dates of mining, present vegetative status and the relationship between the initial vegetation recovery characteristics and the terminal woody canopy density. The information generated will help expand the existing knowledge base of reclaimed mined lands. Reclaimed coal mines exhibit dynamic ecosystem processes, therefore offering the unique opportunity to develop multitemporal analyses which can be potentially applied over broad spatial scales to characterize fundamental landscape change events.

In this dissertation, the term “recovery” is used to describe the establishment of woody vegetation on coal surface mines. Herbaceous-dominant ecosystems are typical in the period immediately after mines have been reclaimed, due to both site conditions and reclamation practice. Once resources necessary to support plant species of greater stature and with greater resource demands are available, woody canopy begins to develop. As such, the extent to which woody canopy has developed is one indicator of ecosystem recovery. However, the different types of woody canopy that may be present can lead to very different interpretations. Where recovering woody canopy is comprised of native forest trees, full and rapid canopy development would be an indication that recovery of ecosystem processes is progressing toward the system’s pre-disturbance state. Where such recovering woody vegetation is comprised predominantly of non-native invasives, the greater likelihood is of progression towards either an “arrested succession” (Groninger et al. 2007) or a “novel ecosystem” (Hobbs et al. 2006) state. Landsat-based recovery assessments have not yet been shown to be able to detect which of these woody vegetation types and associated restoration outcomes are occurring on reclaimed mine sites.

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Chapter 2 Objectives

The overall goal of this study is to develop and apply methods for interpreting Landsat images to identify and characterize woody canopy cover on reclaimed coal mines of central Appalachia. The specific objectives are:

- Assess whether surface coal mines in the heavily forested southern Appalachian regions of USA can be separated from the other prevalent forest-replacing disturbances through automated analysis of an interannual chronosequence of Landsat Thematic Mapper and Enhanced Thematic Mapper Plus images.
- Evaluate performance of a woody canopy cover (including both native and invasive species) estimation method based on the 2011 National Land Cover Database (NLCD) protocol for both mined and non-mined areas of the central Appalachians.
- Determine whether the disturbance/recovery parameters, alone or in combination with variables being used in the 2011 NCLD canopy cover mapping effort, enable robust estimation of woody canopy cover on reclaimed surface coal mines.

Objectives 1, 2 and 3 are detailed in chapters 4, 5and 6 respectively.

Chapter 3 Literature Review

Satellite sensors are well suited to the monitoring of landscape changes through provision of consistent and repeatable measurements of land cover attributes over a large spatial and temporal extent. Past applications of remote sensing techniques concentrated on characterizing the ecosystem structure to establish a baseline condition (Lunetta and Elvidge 1998). With advancement in the science of remote sensing and increase in the computational capabilities, the research community moved from use of hard copy image to digital techniques. The existing advanced techniques can not only map the land cover conditions but can also study the dynamic changes and quantify them in a wide variety of ecosystems (Coppin et al. 2004).

This literature review analyses publications related to remote sensing techniques applied to vegetation change detection. It discusses the achievement of previous studies that have analyzed similar phenomenon that this study attempts to investigate. The purpose of this review is not only to present an up to date idea about the state of research and the established ideas in this field, but also to justify the background for this proposed study.

3.1. Remote sensing in coal mines

Satellite remote sensing can be a helpful tool for environmental monitoring and reclamation studies in open cast mining areas owing to their capability for repetitive multispectral imaging of large areas in a much more cost and time effective way compared to other methods (Schmidt and Glaesser 1998). Commonly, studies in past had focused on distinguishing mined from non mined areas using analogue interpretation of aerial photographs (Mamula 1978). After the launch of Landsat in 1972, several researchers began using satellite data for monitoring mining activities. Most of the studies distinguished bare surfaces of mining from those with vegetation cover(Coker 1977; Collins 1991). With advent of newer digital technologies and higher resolution sensors, studies moved to topics like classification of vegetation classes on reclaimed mines (Parks 1987), classification of geological and geomorphological features on open cast mines (Chatterjee et al. 1996), and spectral separability of mined and reclaimed areas (Schmidt and Glaesser 1998). Remote sensing techniques, particularly those applied using Landsat images were used over a variety of mining locales including India's Jharia coalfields (Prakash and Gupta 1998), abandoned mine wastes of tri-state mining region of Kansas, Oklahoma and Missouri (Xiao H. 2007), coal mining in eastern Germany (Antwi et al. 2008), mountaintop coal mining in west Virginia (Wickham et al. 2007). While most of these and other mining studies have analyzed the mining ecosystem at one point in time or the change in landscape on a image to image basis, none of them have attempted to characterize the vegetation developmental pattern on a multitemporal scale to study the ecological succession, as is proposed in this study .

3.2. Remote sensing change detection

All ecosystems experience continuous change, caused by natural factors, as well as change due to anthropogenic effects (Coppin et al. 2004). A change in the land cover produces a corresponding change in the spectral signature of the affected land surface. This is the central premise of all spectral change detection techniques. Spectral change can be detected visually by interpreting aerial images or by using digital change detection techniques applied on multi-date satellite images. Analysis of aerial photos often produces accurate results that are suitable to their purposes, though such techniques lack repeatability and are biased by the interpreters' capability in detecting the change phenomenon. Digital change detection techniques facilitate the quantification of change using multispectral and multi-date satellite images. These methods, in addition to being consistent and repeatable, also enable analysis in the non-visual portions of the electromagnetic spectrum (Coppin et al. 2004).

Assessment of inter-annual changes in the vegetation state using remote sensing is commonly referred to as "change detection" (Cohen and Goward, 2004). Change can be a categorical or continuous variable. Categorical schemes are used to detect land cover conversions which mean complete replacement of one land cover type by another e.g. deforestation and land clearing. In most of the studies, a single image has been used to map deforestation and land clearing (Fiorella and Ripple 1993a; Tucker et al. 1984). Separating categories with significant spectral difference is easier in single image classification than multi-image classification. However single image classifications cannot detect continuous change classes, for example cover types showing continuous vegetation growth or destruction. This can only be done by analyzing a multi-image series (Guild et al. 2004). Detection of such land cover modifications calls for processes which characterizes continuous change using multi-date satellite images, a collection of techniques commonly called multi temporal change detection. These techniques involve the transformation of two or more images into a single-band or multi band image which highlights the areas of change (Lunetta and Elvidge 1998). A wide variety of multi temporal change detection techniques have been developed over the last two decades with variable degrees of applicability. Coppin et al., in their 2004 review, have summarized nine such techniques which include post classification, composite analysis, univariate image differencing, image rationing, bi-temporal linear data transformation, change vector analysis, image regression, spectral mixture analysis, multidimensional temporal feature space analysis and a heterogeneous group consisting of hybrid algorithms. Each algorithm has its own merits with respect to production ease, information content and interpretability (Coppin et al. 2004). All these algorithms have been grouped by Coppin et al (2004) as bi-temporal (comparing the same area at two points in time) change detection algorithms. However, availability of optimal scenes is crucial to any bi-temporal change detection methodology, and problematic in many cases. The emerging field of spectral trajectory analysis (comparing the same area over longer time periods with multiple images) circumvents this problem by using multiple images at certain temporal intervals to monitor continuous change events.

3.3. Spectral trajectory analysis

Spectral trajectory analysis is a newly emerging field in the area of multi temporal change detection. This technique compares temporal developmental curves or temporal trajectories of spectral values (or derived indices) of land cover change characteristics (Coppin et al. 2004). ‘Trajectory’ when applied to this context, represents the stages of development in an ecosystem (Schroeder et al. 2007). Since the major land cover change in natural ecosystems is the change in vegetation, a trajectory constructed from time series vegetation data becomes the surrogate for the evolving vegetation process (Halpern 1989). The deviation of the trajectory from its normal or expected path detects a change event (Lambin and Strahler 1994). Vegetation growth curves have long been used to study the plant community responses to disturbance and have been found to reveal important information on the succesional mechanism (del Moral et al. 2009; Halpern 1989). Such an idea was first used in the remote sensing context by Lawrence and Ripple, when they characterized the vegetation change curves obtained from a time series of Landsat TM to analyze the change in vegetation due to a volcanic eruption at mount St. Helens (Lawrence and Ripple 1999). They studied eight Landsat images and their estimated cover images using different change trajectories. Their study demonstrated the utility of change trajectories in explaining the vegetation response of individual pixels.

Schroeder *et al.* (2007) used spectral trajectories to characterize the dynamic succession of woody vegetation in areas where both herbaceous and woody vegetation were growing together. Working in forest harvest sites in western Oregon, they extracted time series of pixel level tree cover estimate to characterize forest re-growth patterns. These patterns were then categorized into forest re-growth classes using CART (Classification And Regression Tree) classification model which resulted in fair to moderate agreement with test samples (Schroeder et al. 2007).

Song *et al.* (2007) applied the spectral trajectory approach to characterize forest successional stages in southern Oregon, using Tasseled cap greenness and brightness indices as estimators of the successional stages. It was reported that multitemporal estimators achieved R^2 values of 90% compared to the 50% R^2 values obtained from single image estimators (Song et al. 2007).

Kennedy *et al.* (2007) used spectral trajectories to devise an automated change detection technique to identify forest disturbance. They rationalized that the pattern of spectral value change is distinctive both before and after the disturbance event and therefore can be used as an indicator of the event. They used the Landsat band 5 reflectance or Short wave infrared (SWIR) as the estimator of vegetation and formed four hypothesized models of disturbance and revegetation. If an area fitted the trajectory of any of these four models according to a least-square measure of goodness of fit, it is likely to have experienced the event described by the trajectory. The study resulted in a 90% agreement between the algorithm and the interpreter in areas of clear cut, and a 74% in areas of thinning (Kennedy et al. 2007).

Kennedey et al (2010) introduced a new trajectory-based algorithm: LandTrendr (Landsat-based detection of trends in disturbance and recovery) to detect disturbance and recovery using the Tasseled cap suite of vegetation indices to construct the trajectories. They “despiked” the Landsat trajectories to eliminate noise and then performed temporal segmentation of the trajectories by using a sequence of straight lines to capture the broad features of the trajectory. Using both regression- and vertex-to-vertex-based trajectory fitting to detect abrupt events as disturbance and longer-duration processes as regrowth, the algorithm captured abrupt disturbance events such as fire and harvest, as well as longer duration processes such as loss in vegetative vigor due to insect attack, or post-disturbance recovery.

Huang et al (2010) developed the Vegetation Change Tracker (VCT) algorithm to detect forest disturbances by reconstructing the disturbance history using dense stack of Landsat images. Using a forest likelihood measure to construct their forest disturbance trajectories, Huang et al analyzed several parameters to characterize disturbance and recovery. Some of the parameters that they used were: disturbance year, disturbance magnitude in the form of increase in spectral score from disturbance year to the consecutive year, R^2 values of the line fitted to recovery curve and the slope of that line. They reported 80% accuracy in detecting disturbance where an annual time series was used.

3.4. Landsat data

The Landsat program is a series of earth observing satellite missions jointly owned by the NASA and the U.S Geological Survey. Landsat has continuously collected spectral information about the earth’s land cover features for the last 30 years, and created an unparalleled archive which has given the scientists the ability to study continuous change events. Launched in 1972 as the Earth Resources Technology Satellite (ERTS) and later renamed Landsat, these data have been continuously used for myriad ecological monitoring applications. Landsat data has several advantages in this regard (Cohen and Goward 2004). It offers the longest running time series of systematically collected remote sensing data. The Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) acquire spectral measurements in several portions of the solar electromagnetic spectrum which are sensitive to vegetation and its changes. The grain size for these data matches the grain of land management activities such as mining and therefore can monitor such activities effectively. All these advantages have encouraged its applications in ecological studies. Analyses of Landsat has involved the study of the ecosystem state and its temporal dynamics (Cohen and Goward 2004). Several studies have conducted thematic classification using Landsat data where the usual approach is identifying the spectral properties with classes of interest and assigning the class label to those image pixels (Cohen et al. 2001; Hansen et al. 2002). Following the early work of Blair and Baumgardner (1977) who demonstrated with their multitemporal study that Landsat data could be used to characterize the greening and senescence of vegetation, researchers have characterized the inter- and intra-annual dynamics of ecosystems (Lefsky et al. 2001; Skole and Tucker 1993). Some have derived continuous estimates of vegetation biophysical parameters from Landsat data such as Leaf Area Index (LAI), specific leaf area, canopy moisture content, canopy cover, biomass etc. (Hunt et al. 2006; Kodar et al. 2008; Toomey and Vierling 2006; Zheng et al. 2008).

It is expected that with the recent no-cost provision and uniform pre-calibration of Landsat data many more researchers and land managers will be encouraged to apply these data to address a wide variety of ecological issues in a global scale.

3.5. Vegetation indices

A vegetation index is a dimensionless, radiation based measurement, which is computed from an algebraic combination of multispectral reflectances of remotely sensed data. These indices are used to analyze vegetation properties by isolating vegetation contribution from those of other materials (Asner et al. 2003). Jensen (200) defined it as dimensionless, radiometric measures that function as indicators of relative abundance and activity of green vegetation, often including LAI, percentage green cover, chlorophyll content, green biomass, and absorbed photosynthetically active radiation. Spectrally derived vegetation indices have been widely used in vegetation studies, often involving quantification of some vegetation attribute (Cairns et al. 1995) . Blair and Baumgardner (1977) proved with their seminal study that vegetation indices were more sensitive to vegetation and its phenology than single band reflectance. Over the years, vegetation indices have been used to address several issues such as vegetation change detection, inventorying of carbon stocks, impact of human activities and natural calamities and many more. Running et al (1994) and Huete et al. (1994) underlined the essential attributes of a vegetation index, which are:

- Maximize sensitivity to the plant biophysical parameters
- Normalize external effects, such as sun angle, viewing angle and atmospheric influences for consistent spatial and temporal comparisons.
- Normalize canopy background variations, variations caused by topography, soil, and non-photosynthetic canopy components
- This section describes some of the numerous vegetation indices that have evolved on relation to different applications of vegetation studies.

Vegetation shows differential behavior with respect to absorption, transmittance and reflectance in the red and infrared part of the electromagnetic spectrum. Several studies have taken advantage of this difference and formulated indices based on this differential behavior (Jensen 2000; Lyon 1995). Some of the basic techniques include difference of the NIR and red bands, division of the NIR by the red band, and combinations of both to provide normalizations (Lyon et al. 1998; Perry and Lautenschlager 1984)

3.5.1. Ratio based indices

Normalized difference vegetation index (NDVI): This is a simplistic measure of the vegetation 'greenness' that is computed as the difference divided by sum of the Near Infrared (NIR) and Red (R) spectral reflectance. It takes advantage of the differential reflection of vegetation in NIR and R bands of the electromagnetic spectrum, since green vegetation reflects the NIR and absorbs the red due to chlorophyll absorption.

$$NDVI = \frac{NIR - R}{NIR + R} \qquad \text{Equation 3-1}$$

The values range from -1 to +1 indicating no vegetation and abundant vegetation respectively. Though one of the first indices to be developed (Rouse 1973), it has been and is being used in a variety of vegetation studies all over the world. NDVI is related to vegetation variables like leaf area index (LAI), photosynthetically active radiation (PAR), biomass, productivity etc. (Asrar et al. 1984; Richardson and Wiegand 1977). The normalization included in NDVI has made it resistant to sensor calibration defects and atmospheric effects (Huete 1988; Justice et al. 1985). This traditionally used index has been successfully used by many studies some of which are environmental quality monitoring, vegetation succession and productivity (Lefsky et al. 2001; Schroeder et al. 2007), forest phenology (White et al. 1997), surface coal mine detection and revegetation (Prakash and Gupta 1998; Wickham et al. 2007; Xiao 2007) and several others.

Although NDVI is the most widely used vegetation index, it has been reported to become unreliable in certain instances. NDVI is influenced by factors other than vegetation itself. It is affected by soil and atmosphere thereby introducing many sources of error in the assessment of green vegetation. Huete and Jackson (1987) identified several factors that affected the NDVI and rendered it unreliable in accurate assessments. They found that the brightness and color of the background soil and litter affected the NDVI measurements, particularly in case of partial canopies. Their study revealed that darker soil and litter cause an increase in the NDVI while lighter colored soils and litter tend to decrease the index value; red bare soil and yellow litter cause an inflation in the index value while gray litter induces lower values. They concluded NDVI is rendered unreliable in areas where there are significant soil brightness variations, which may be caused by differences in soil moisture, organic matter concentration and shadowing. Other than soil, they also found the standing senesced vegetation from previous year's growth to be another factor that interferes with the NDVI's reliability. The problem was severe where emerging green vegetation was occluded by taller senesced grass causing the emergent flux from the canopy to have a yellow dead vegetation signal.

Soil adjusted vegetation index (SAVI) was developed to minimize this soil-brightness influence on NDVI, particularly in cases of partial canopies where the NDVI was found to inaccurately represent the situation (Huete 1988).

SAVI= $(1 + L)(NIR - R) \div (NIR + R + L)$,   Equation 3-2

Where L (~ 0.5) is the adjustment factor that accounts for the differential red and NIR extinction through the canopies. In a live green canopy, the red extinction far exceeds that of NIR. This causes more reflection of NIR off the canopy background than that of red. This background reflection interferes with the canopy signature, thereby affecting both the ratio indices (e.g NDVI) and orthogonal indices (e.g. Tasseled cap indices, PVI). The ‘background correction’ factor L was found to reduce soil noise problem significantly.

Another external factor that causes the NDVI to vary is the sun/sensor geometry. Epiphanio and Huete (1995) studied the effects of solar and sensor geometry on NDVI. They explained that variations in solar angle alter the canopy illumination and optical thickness, thereby decreasing the red and increasing the NIR reflectance. Since NDVI is a normalized ratio of the red and the NIR band, it increases due to the increase in solar zenith angle. They also found that a decrease in the sensor view angle decreased the NIR and red reflectance, thereby reducing the overall NDVI values. Hence the change of solar zenith angle and the sensor view angle from one image to the next (especially if they are from different seasons) can result in inconsistent NDVI values.

Kaufman and Tanre (1992) developed the **atmospherically resistant vegetation index (ARVI)** to counter the atmospheric influences on NDVI. This index takes advantage of the blue channel and uses the difference in radiance between red and blue channels to correct the radiance in the red channel.

ARVI= $(\rho_{nir}{*} - \rho_{rb}{*})/(\rho_{nir}{*} - \rho_{rb}{*})$, Equation 3-3

Where $\rho_{rb*} = \rho_{red*} - \gamma\,(\rho_{blue*} - \rho_{red*})$, γ is a function to correct radiance in the red channel and make the index stable to spatial and temporal fluctuations in aerosol content, and ρ^* are reflectances with prior corrections for molecular scattering. This index was four times more resistant to atmospheric effects than NDVI, the effects being particularly visible in the vegetated areas rather than the bare soil ones (Kaufman and Tanre 1992).

Liu and Heute (1995) proposed to combine the SAVI and ARVI and create a **modified normalized difference index (MNDVI)** that would minimize both soil and atmospheric noise, thereby stabilizing NDVI to a greater extent.

MNDVI= $NDVI\frac{(1+C_2H_2)}{(1+C_1H_1)}$,　　　　Equation 3-4

Where, H_1 and H_2 are functions of the blue, red and NIR reflectances, atmospheric, canopy backgrounds and vegetation feedback coefficients. C_1 and C_2 are the weight functions dependent on the degree of correction for atmosphere. Heute (1996) simplified this equation and named it **SARVI2**.

SARVI2= $2.5\frac{(\rho_{nir}-\rho_{red})}{(1+\rho_{nir}+6\rho_{red}-7.5\rho_{blue})}$　　　　Equation 3-5

Where, ρ are apparent directional reflectance. They showed that SARVI2 removed smoke plumes and cirrus clouds from Landsat imagery signifying its ability to remove atmospheric noise.

Simple ratio (SR): Devised by Jordan in 1969, this is the most simplistic representation of a vegetation index in the form of a ratio of the NIR and R bands.

$SR = \frac{NIR}{R}$　　　　Equation 3-6

Reduced simple ratio (RSR): This ratio was proposed by Brown et al (2000). It utilizes the Simple Ratio and the SWIR band and minimizes sensitivity to the background.

$RSR = SR[1-\frac{SWIR-SWIR_{min}}{SWIR_{max}-SWIR_{min}}]$　　　　Equation 3-7

Where $SWIR_{min}$ and $SWIR_{max}$ are SWIR reflectances from closed and open canopies respectively. Several researchers noted that this ratio has increased sensitivity and improved correlation to the Leaf Area Index (LAI) in comparison to SR or NDVI (Brown et al. 2000; Stenberg et al. 2004; Tian et al. 2006).

Normalized difference moisture index (NDMI): This index is a measure of the canopy water content and is closely related to the changes in plant biomass an water stress (Hardisky et al. 1983). It is computed as a normalized ratio of the Landsat (TM/ETM+) band 4 and Short Wave Infrared (SWIR) band 5.

$NDMI = \frac{NIR(4)-SWIR(5)}{NIR(4)+SWIR(5)}$　　　　Equation 3-8

Horler and Ahern reported that the SWIR band explained the forest structure and its changes, more effectively than other indices (Horler and Ahern 1986). Another study compared the efficiencies in NDMI and Tasseled Cap wetness and found the former to be slightly more efficient in detecting forest clear cuts (Jin and Sader 2005). Studies which have used a simpler TM band5(SWIR) / band 4 (NIR) ratio have also reported their correlation with ground based measurements of forest damage (Vogelmann and Rock 1988).

3.5.2. Orthogonal indices

Tasseled cap indices*:* This index was derived based on the consideration that spectral development of open canopy forest vegetation and agricultural crops incorporate soil spectral reflectance (Kauth and Thomas 1976). Kauth and Thomas statistically rotated the MSS data space to derive the Brightness and Greenness indices. This was followed by the simplification of a plane of soils and a conceptual soil line. With the advent of Landsat TM, these indices were re-calibrated and the wetness band was added using available SWIR bands. The new model of 'TM Tasseled Cap' (Crist and Cicone 1984) included three vegetation indices brightness, greenness and wetness which together formed the plane of vegetation (brightness and greenness), plane of soils (brightness and wetness) and the transition zone (wetness and greenness). Several researchers have used these indices to monitor land cover changes (Cohen and Spies 1992; Fiorella and Ripple 1993a, b; Rogan et al. 2002). This group of indices is a guided principal component analysis using the Gram-Schmidt orthogonalization procedure (Kauth and Thomas 1976). The TC indices preserve most of the original spectral information of the Landsat TM data and with the exception of wetness, is physically interpretable (Cohen et al. 1995).

Brightness is the first feature of the TC group of indices and is the weighted sum of the six reflective TM/ETM+ bands. It is responsive to changes in total reflectance and all factors that are responsible for it. This index is extremely responsive to the differences in soil brightness but not particularly to the variation in vegetation density (Crist and Cicone 1984).

Greenness: This index is particularly responsive to the green vegetation density since it responds to the combination of high absorption in the visible bands and high reflectance in the NIR. Along with brightness, greenness defines the 'plane of vegetation'.

Wetness, though suggestive of the moisture content in a component, is actually more responsive to the interaction between the moisture content and the structure of the component (Cohen et al. 1995). Lakes are less moist in comparison to clouds, snow or conifer foliage. This prompted the suggestion of change of nomenclature to maturity index (Cohen and Spies 1992) or structure-wetness index (Cohen and Spies 1992). Several studies have demonstrated that wetness index is valuable for discriminating within closed canopy stands. A major advantage with this index is that it is relatively insensitive to topographic variation (or the cosine of incidence angle). It was named thus since it highlighted the moisture related scene characteristics.

Disturbance index (DI): Disturbance index was designed by Healy et al. (2005) to highlight forest areas that had been disturbed and found to have significantly different spectral signatures from undisturbed forests. This index is a linear combination of the three Tasseled Cap (TC) indices: brightness, greenness and wetness (Crist and Cicone 1984). The computation of this index is based on the assumption that clearcut areas have high brightness values but low greenness and wetness values. Before computation of this index, each TC band was rescaled using the standard deviation above and below the mean forest (undisturbed) value, using the following equations:

$$B_r = (B - B_\mu) / B_\sigma$$ Equation 3-9

$$G_r = (G - G_\mu) / G_\sigma$$ Equation 3-10

$$W_r = (W - W_\mu) / W_\sigma ,$$ Equation 3-11

Where B, G and W are the brightness, greenness and wetness bands, subscript ‘r’ signifies the rescaled band, subscript μ shows the mean value for undisturbed forest and subscript σ shows the standard deviation. Once the components are normalized, they can be combined using the following equation:

$DI = B_r - (G_r + W_r)$ Equation 3-12

It can be expected that disturbed areas will have higher values owing to high positive B and low negative G and W, while the undisturbed areas will have lower DI values, thereby identifying the disturbed landscapes (Healey et al. 2005) .

Perpendicular vegetation index (PVI): This index was developed by Richardson and Weigand (1977), with the same consideration of soil spectral interference as the Tasseled Cap indices, and accounted for soil background variations. It was stated that the perpendicular distance from the soil line could be used as an indicator of the plant development (Richardson and Wiegand 1977).The soil line in this case was a two dimensional analog of the Kauth-Thomas soil brightness index that was estimated by linear regression.

$PVI = (NIR - aR + b)/\sqrt{a^2} + 1$, Equation 3-13

Where, a and b are slopes and offsets of the soil line.

3.6. Vegetation class determination: Classification techniques

Extracting vegetation cover class information from Landsat imagery has been a vigorous research activity for the past 30 years. The usual approach of classification involves ‘identifying spectral properties associated with classes of interest and then assigning class labels to image pixels with those properties’ (Cohen and Goward 2004). There are two broad classes of classification procedure, the unsupervised and supervised classification techniques. In unsupervised classification pixels are assigned to spectral classes by a clustering process, where the analyst has no prior information of the spectral classes. On the other hand, a supervised classification assumes that classes can be modeled using probability distribution of the statistical parameters of their distributions in the spectral space (Richards and Jia 2006). While unsupervised techniques have gained prominence in large area classifications (Cihlar et al. 1996; Vogelmann and Rock 1988), supervised classifications have been used to separate spectrally similar vegetative cover types on a regional scale (Bauer et al. 1994; Hansen et al. 2002). Both the supervised and unsupervised techniques have their drawbacks. The time and effort of the analyst in spectral class training prior to supervised classification has been identified as a major disadvantage (Bolstad and Lillesand 1992). Unsupervised classifications bypass this problem by automatic grouping of pixels based on spectral statistics (Wayman et al. 2001). However this method also has drawbacks, such as a-posteriori labeling of spectral classes by the analyst, a time consuming and biased method (Bauer et al. 1994). While the bulk of these techniques have been employed on a single scene classification, a handful of studies have also used time series of satellite images to classify vegetation cover types. An example of the later is the Bauer et al. (1994) study that used six Landsat TM scenes to map seven forest cover classes in North east Minnesota. They tested the supervised and unsupervised classification techniques and found both of them to be unsuitable in labeling all the target forest cover classes. An alternative hybrid classification technique called guided clustering proved to be much more efficient in their case. This method made use of the analyst defined training data and clustered each class into several spectrally homogeneous sub classes. All the sub classes were classified using a maximum likelihood classification and were then regrouped into the target classes. This technique proved to be highly efficient and suitable for large area application.

There was simultaneous effort to increase the repeatability and accuracy of land cover classifications while reducing the user time and effort. Multi-stage iterative classifications were pursued by several researchers (Jensen et al. 1987; Rutchey and Vilcheck 1994; SanMiguelAyanz and Biging 1997) that produced superior results than single-stage classifications. Jensen et al (1987) introduced the 'cluster-busting' technique that used specific rejection criteria to reject confused spectral classes. Inspired by this approach, Wayman et al (2001) developed the Iterative Guided Spectral Class Rejection (IGSCR) algorithm, a multi-stage hybrid classification technique that accepted and labeled a spectral class if it met the desired inclusion threshold, and rejected if otherwise. The inclusion threshold signified 90% homogeneity and minimum of ten reference pixels. The labeled pixels were removed from the original image and the classification continued on the unlabeled pixels which were clustered into new spectral classes in the next iteration. This continued till the ending criteria were met, after which the known spectral classes were combined into a new spectral class and maximum likelihood decision rule used to classify the image. Musy *et al.* (2006) automated this algorithm and improved upon it to make it less prone to error and less time consuming for the analyst. The present IGSCR algorithm needs the user only to input the image and select training data and parameters, after which the whole process is user independent (Musy et al. 2006). IGSCR has been reported to generate greater accuracies in labeling land cover classes than supervised or unsupervised classification techniques (Kelly et al. 2004; Wynne et al. 2007).

However, these hard classification techniques result in a categorical classification of the land cover, with only one cover type assigned to each pixel. A mined land cover, in many instances present a mixed pixel scenario, where the herbaceous cover is mixed with woody tree species and the whole system is in a transitional stage, with varying quantities of woody canopy cover. Hence, there is need to classify the woody canopy cover using a continuous classification scheme, rather than a categorical one. Previous efforts to estimate tree canopy density as a continuous variable have utilized linear spectral mixture analysis (SMA) (Elmore et al. 2000; Roberts et al. 1993) or linear regression techniques (De Fries et al. 1998; Iverson et al. 1989; Zhu and D.L. 1994). Other techniques such as fuzzy logic and neural networks have been used (Foody and Cox 1994), though some claim that they are not robust enough to be used in large scale applications (Li and Strahler 1985; Maselli et al. 1995). Linear Spectral Mixture Analysis has been proven to work in landscapes that are comprised of a mixture of vegetation types, differential canopy shadowing and potentially exposed soil, e.g. reclaimed mine habitat. Conceptually the occurrence of multiple materials or endmembers within a pixel leads to mixed spectral signal. The spectral reflectance of an endmember represents the signature of a pure or unmixed pixel. With known number of endmembers and known spectra for each endmember, the observed pixel value is modeled by linear combination of the spectral response of components within the pixel. However a major disadvantage of SMA is that it cannot predict tree canopy density directly, since tree canopy is not a spectral endmember (Roberts et al. 1993). Linear models that are used by both the SMA and liner regressions estimate the relationship between canopy density and spectral signal. However they fail to work efficiently in large areas where the relationship becomes more complex due to variability in spectral reflectance of tree canopy over variable geographic locations and variability in the atmospheric conditions (Borel and Gerstl 1994; Ray and Murray 1996). The regression trees prove more effective in such conditions, since it approximates the complex relationships using a set of linear models, which have been reported to produce greater accuracies than a single linear regression model (Huang and Townshend 2003; Huang 2001).

3.7. References

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Chapter 4 Identifying Revegetated Mines as Disturbance/Recovery Trajectories Using an Interannual Landsat Chronosequence

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In review: Photogrammetric Engineering and Remote Sensing

Disturbance and recovery metrics derived from analysis of inter-annual Landsat data spanning 25 years revealed that (1) surface coal mines can be separated from other forest-replacing disturbances, and (2) object-based analysis is more accurate than pixel-based analysis.

4.1. Abstract

The objective of this study was to assess whether surface coal mines in the heavily forested southern Appalachian regions of USA can be separated from the other prevalent forest-replacing disturbances through automated analysis of an interannual chronosequence of Landsat Thematic Mapper and Enhanced Thematic Mapper Plus images. Forest replacing disturbances were first identified using a vegetation index (VI) threshold, then classified using descriptors of the disturbance/recovery trajectory: disturbance minimum, recovery slope and recovery maximum. Three VIs (normalized difference vegetation index or NDVI; the tasseled cap greenness/brightness ratio, TC G/B; and the inverse of Landsat band 3, B3I) were used to analyze multitemporal trajectories, generated using both pixels and objects. Classification accuracies using objects were better than those obtained using pixels for all VIs. The highest object-based classification accuracy was achieved using TC G/B (89%), followed by NDVI (88%) and B3I (80%). The diagnostic parameters in mined trajectories were found to be distinctly different from other landscape disturbances, leading to a satisfactory classification based on disturbance/recovery trajectories.

4.2. Introduction

Surface coal mining has been a major industry in Appalachia, USA, since the 1960s, and continues today. In response to concerns over the land resource impacts of coal mining, the USA established a national law to mandate uniform standards for reclamation of these areas in 1977, the Surface Mining Control and Reclamation Act (SMCRA). Approximately 1.5 million acres have been mined and reclaimed under the SMCRA in the eastern U.S.A. (Zipper 2007), primarily within the Appalachian mountains, which host the most extensive temperate deciduous forests in the world (Angel et al. 2005). Under SMCRA, mined areas are mandated to be revegetated promptly as needed to stabilize the land surface and control erosion, and to be reclaimed to a landuse capability that is equal to or higher than that which preceded mining (Title V, Sec. 515a and 501 c3; SMCRA, 1977. In Appalachia, many mines have been reclaimed with herbaceous vegetation for the purpose of meeting regulatory standards, but such lands often are not used for agriculture or for other managed purposes (Angel 2005). Other common post-mining land uses have included wildlife habitat and unmanaged forest (Burger et al. 2005a), often through establishment of both fertilized grasses and woody species that, although able to survive on mining sites are not common in the region's native forests. Rapid revegetation with fertilization and thick grass cover has been a standard practice, encouraged by regulatory agencies under SMCRA (Angel 2005). Although native forests are now being restored on some mining sites today (Burger et al. 2005b) most of the region’s mined lands are unused grasslands and "shrub lands" that are in various stages of arrested plant succession (Groninger 2007). It is possible for such lands to be converted to productive native forest vegetation, but such conversions require investment for cultural treatments and/or soil mitigation (Zipper and Burger 2010).

The potential for conversion of unused post-SMCRA mined land to woody biomass production uses is also being investigated (Groninger et al. 2007). Successful conversion of post-SMCRA mined lands to productive and ecologically beneficial uses would produce public benefits. The first step in developing effective conversion strategies is to acquire accurate information on the extent of such areas and their current vegetation status. Information of this nature is generally not available in published or electronic data records (Zipper 2007). These lands are located over a large area, and obtaining physical access to individual tracts is often difficult. Thus, the need to characterize these lands is a problem that lends itself to a remote sensing application.

Remote sensing techniques have been widely used to locate surface mines (Chatterjee et al. 1996; Latifovic et al. 2005; Parks 1987; Schmidt and Glaesser 1998; Xiao 2007). Rathore and Wright (1994) have reviewed several early studies of remote sensing applications to mine mapping, which achieved varying degree of success. Most studies were relatively straightforward, using single-date imagery. Even when multiple images were used, the approach was year-to-year bitemporal change detection (Guild et al. 2004). Very few studies have attempted to delineate reclaimed mines. In areas affected by coal mining under SMCRA and reclaimed using conventional pre-FRA approaches, fully-revegetated reclaimed mines are often spectrally indistinguishable from other land uses (Townsend et al. 2009).

Since fully vegetated reclaimed mines cannot be easily differentiated from other landuses at one point in time, use of single-date imagery is ill suited to detection of mining areas and impacts, as they have occurred through time. Surface mining is an ecological disturbance that is anthropogenic in nature, and produces a distinctive disturbance and recovery pattern through time. A small but increasing body of literature has shown that disturbance and post-disturbance recovery of forest ecosystems can be well-characterized by analyzing spectral changes through time using earth resource satellite data. This approach was used by Lawrence and Ripple (1999) when they analyzed vegetation index trajectories obtained from a time series of eight Landsat TM images to quantify the vegetation change caused by a volcanic eruption at Mount St. Helens. Schroeder *et al.*, (2007) used spectral trajectories to characterize the dynamic succession of woody vegetation in areas where both herbaceous and woody vegetation were growing together. Song *et al*. (2007) applied the spectral trajectory approach to characterize forest successional stages in southern Oregon using tasseled cap greenness and brightness indices as estimators of the successional stages. They explained more than 90% of the variance with multitemporal estimators, in contrast to only 50% using single image estimators. Kennedy *et al*., (2007) used spectral trajectories to devise an automated change detection technique to detect forest disturbance on a dense stack of Landsat images. Using the short-wave infrared (SWIR; Landsat TM band 5) as the estimator of vegetation they developed four hypothetical trajectories of disturbance and revegetation: (a) simple disturbance, (b) disturbance followed by exponential revegetation, (c) revegetation from disturbance prior to observation record, and (d) revegetation from prior disturbance. Classes were assigned based on a trajectory matching exercise. The study resulted in a 90% agreement on overall change/no-change between the algorithm and the interpreter, and 84% agreement on the year of disturbance. Such trajectory-based approaches, however, have not been applied in studies of mining disturbances.

We applied trajectory-based methods to characterize the temporal dynamics of vegetation disturbance and regrowth in the reclaimed coal mines of Appalachia, using a co-registered stack of annual available Landsat images extending from 1984 to 2008. Our objective was to develop and test a method that provides automated identification of reclaimed mines and defines year of disturbance. Our approach is based on the premise that the spectral responses of mining and reclamation create a unique temporal pattern or trajectory that is diagnostic in identifying reclaimed mines. We hypothesized that the singularity of the mining disturbance and recovery trajectory enables separation of reclaimed mines from the background forest and other landscape disturbances. Based on an understanding of coal mining, mandated reclamation practices, and resulting post-mining vegetation development processes, we developed a technique for detecting coal surface mines by characterizing vegetation disturbance/recovery trajectories. We assessed the effectiveness of that technique by comparing classification accuracies of pixel- and object-based applications with three vegetation indices: tasseled cap greenness/brightness index (TC G/B), Landsat band 3 inverse (B3I), and the normalized difference vegetation index (NDVI).

4.3. Methods

4.3.1. Study area

The study area includes four prominent coal mining counties of southwestern Virginia, Wise, Dickenson, Buchanan and Russell (Figure 4.1). Extensive surface coal mining has been conducted in these areas since the 1960s. Most of the non-mined area, and more than two thirds of the total area, is forested with mixed hardwoods. The study area also has ample representation of other forms of forest conversion such as roads, urban areas, and other forms of landscape development. There is some agriculture, in the non-coalfield segments of the study area, but agricultural land uses within the coalfield are primarily livestock grazing on former coal mines.

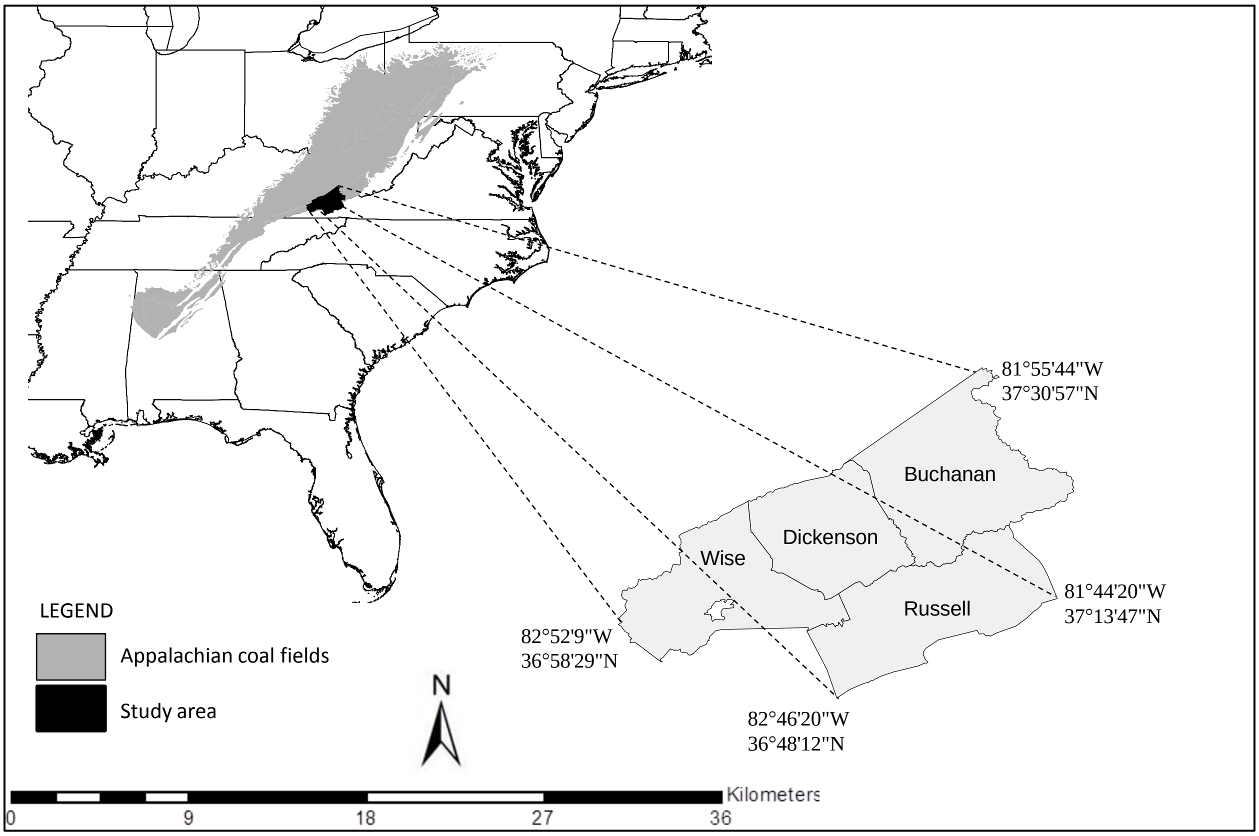

Figure 4.1. Location of the study area encompassing the coal mining counties of southwestern Virginia.

4.3.2. Data and pre-processing

The image dataset (Table 4.1) consisted of 23 annual Landsat (22 Landsat-5 Thematic Mapper, TM and one Landsat-7 Enhanced Thematic Mapper, ETM+) images (WRS-2 path 18 row 34), extending from 1984 through 2008. Because of extensive cloud cover in all available leaf-on images from 1992 and 1996, these two years were not represented in the image sequence. Every other year was represented by a single image, selected from all available leaf-on images.

The Landsat images were downloaded from the U.S. Geological Survey Glovis site (http://glovis.usgs.gov). The images were acquired at level 1T (with terrain correction). The co-registration of the images was verified to avoid errors due to mis-registration. Radiometric and atmospheric correction were applied by using advanced correction algorithms implemented as automated routines in the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS), a protocol designed for processing large quantities of Landsat images (Masek et al. 2006). The surface reflectance products were used. Clouds and cloud shadows were visually identified, delineated in individual images by manual digitization, and excluded from analysis.

Table 4.1. List of Landsat image dates, their sensor types and assigned number in the chronosequence. Images from years 1992 and 1996 were unavailable due to the high frequency of cloud cover in the growing season images.

Image date	**Sensor type**	**Assigned number in the chronosequence**
9/17/1984	TM	1
9/20/1985	TM	2
6/19/1986	TM	3
6/6/1987	TM	4
6/8/1988	TM	5
6/11/1989	TM	6
6/30/1990	TM	7
9/21/1991	TM	8
6/6/1993	TM	9
8/28/1994	TM	10
8/31/1995	TM	11
9/5/1997	TM	12
5/19/1998	TM	13
9/3/1999	TM	14
6/9/2000	TM	15
8/15/2001	TM	16
5/22/2002	ETM+	17
6/2/2003	TM	18
9/24/2004	TM	19
9/11/2005	TM	20
7/12/2006	TM	21
9/17/2007	TM	22
9/3/2008	TM	23

4.3.3. Selecting vegetation indices

The choice of a VI is crucial to mine identification, so we executed a preliminary trial for the selection of indices best suited to the study purpose. Several multispectral VIs were tested including normalized difference vegetation index (NDVI) (Rouse 1973), normalized difference moisture index (NDMI) (Hardisky et al. 1983; Jin and Sader 2005), simple ratio (SR), reduced simple ratio (RSR) (Brown et al. 2000), disturbance index (DI) (Healey et al. 2005), tasseled cap indices brightness, greenness and wetness (Crist and Cicone 1984), and tasseled cap greenness-brightness ratio index (TC G/B) (Foody 2004). Landsat bands 3, 4 and 5 were also tested given demonstrated relationships with forest disturbance, regrowth, and related biophysical parameters (Coleman et al. 1990; Eklundh et al. 2001; Liu et al. 2002; Meng et al. 2009; Schroeder et al. 2011). VIs were computed for each image and images were stacked. 200 random points with equal representation in disturbed (both urban and mining) and undisturbed (forests) classes were chosen using aerial images (NAIP, DOQQ and VBMP – see Table 4.2)

At each point, values for each VI were extracted within each image and, for each VI, the lowest value reached in the sequence was determined. Using this minimum value for each VI at each point, a Classification and Regression Tree, CART (v.6.0, Salford Systems Inc.) classification (using the Gini splitting rule and 10-fold cross validation, per Lawrence and Wright (2001)), was conducted to identify the VIs that best separate disturbed from undisturbed points. The prediction accuracy of the disturbed class was compared for all of the indices. NDVI, TC G/B and band 3 were most effective in identifying disturbance the years it occurred (Figure 4.2). NVDI and TC G/B decreased with vegetation removal and increased with vegetation regrowth, but band 3 values showed an opposite pattern. Therefore inverse values were calculated by subtracting band 3 values from a fixed maximum number, 10,000 (scaling factor). The resulting difference was then divided by 10,000. This ratio is called the band 3 inverse (B3I). While we are unaware of any prior study using this as a de facto vegetation index, band 3 has been shown to be very responsive to changes in leaf area (e.g., Eklundh *et al.* 2001).

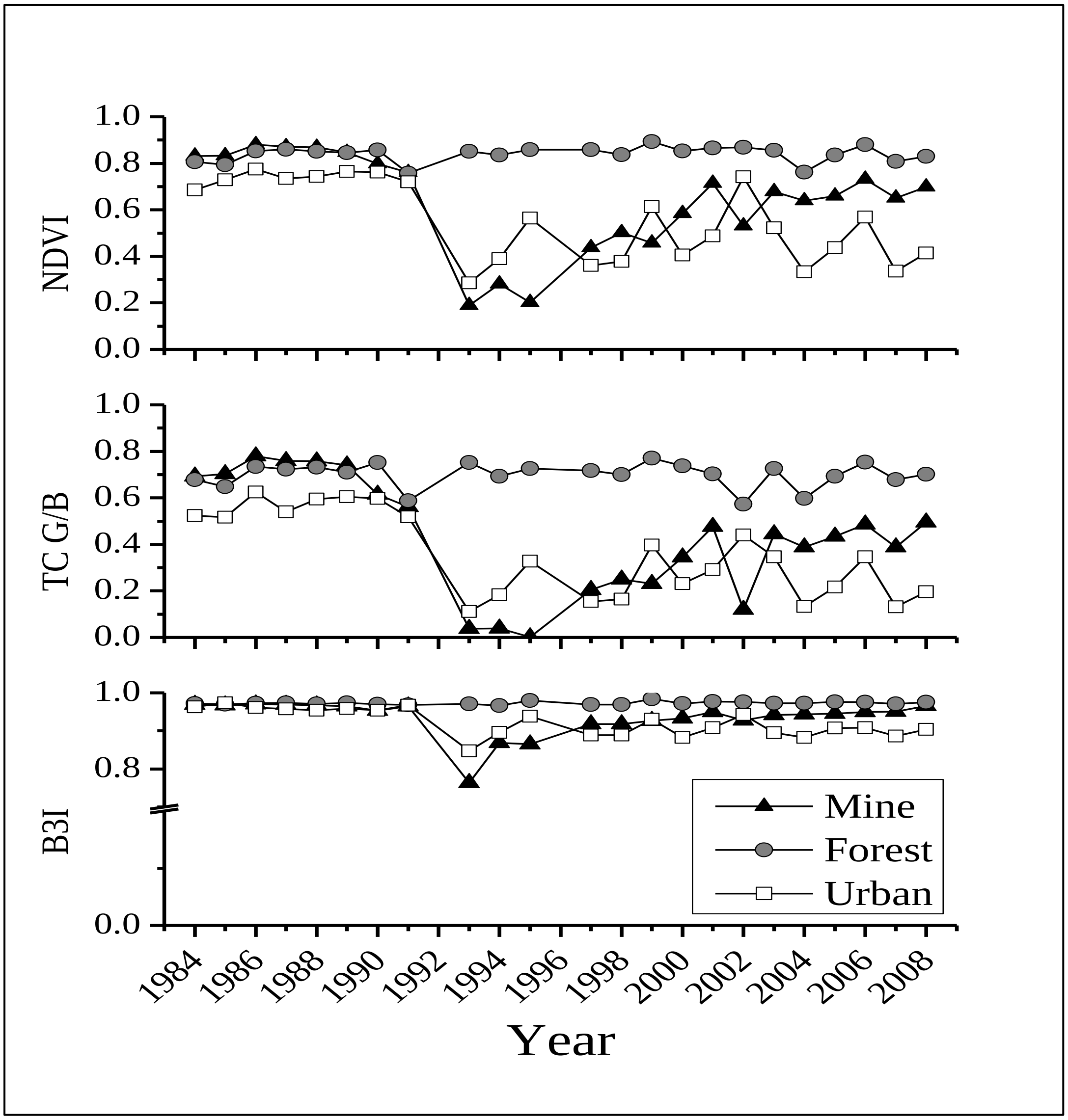

Figure 4.2. Examples of trajectories of mining, urban and forested pixels, computed from *(a)* NDVI, *(b)* TC G/B, and *(c)* B3I. The same pixels have been used for the three VIs. The year of disturbance is 1993 for mining and urban disturbance, in all three VIs.

Table 4.2**.** Ancillary geospatial data used in the study to develop training and validation data.

Data	**Dates**	**Source**
National Agricultural Imagery Program (NAIP)	2003, 2005, 2008	U.S Department of Agriculture (USDA)
Digital Ortho Quarter Quads (DOQQ)	1996-1999	U.S Geological Survey (USGS)
Virginia Base Mapping Program (VBMP)	2002, 2005, 2007	Virginia Geographic Information Network (VGIN)
Land uses, National Land Cover Dataset (NLCD)	1992 and 2001	Multi-Resolution Land Characteristic Consortium (MRLC)
Road data	2000-2008	Virginia Department of Transportation (VDOT)

4.3.4. Converting pixels to objects

Objects are groups of spatially adjacent pixels that are spectrally similar. For each of the three chosen VIs, the 23-image stack was segmented into objects using the multiresolution segmentation algorithm within Definiens Professional (v 5.0, Definiens AG, München, Germany). VI-specific Definiens segmentation parameters are shown in Table 4.3. The object boundaries, with their mean VI values, were exported for each image as shapefiles.

Table 4.3**.** Analysis parameter values used in this study

	NDVI	**TC G/B**	**B3I**
Disturbance/Recovery Classification:			
Mining disturbance threshold	0.58	0.34	0.9
Recovery years used for slope computation	7	7	7
Object Delineation:			
Scale factor	30†	1	70
Homogeneity criteria	*	*	*

† Applied to (NDVI + Band 5)

* Uniform criteria for all indices: color = 0.9, shape = 0.1, compactness = 0.3, smoothness = 0.7.

4.3.5. Disturbance/recovery classification model

Our objective was to develop a methodology that would distinguish the reclaimed mines from undisturbed forests and other landcover disturbances, and to identify dates of mining. Thus, the primary landuse classes of interest were forests, reclaimed mines and 'urban'. The urban class was broadly defined to include roads and road corridor disturbances; residential, commercial, and industrial areas, and conventional urban land uses. Forest harvest and fire has been excluded from the analysis due to their insignificant representation in the study area. The classification was applied as a two-step process to both pixels and objects. The first step was to identify disturbances (urban and mining). The second step classified those disturbances as either mines or non-mines.

Mining in these forested landscapes involves rapid clearing of vegetation followed by extraction of underlying geologic materials. Mining is followed by reclamation activities: site and soil reconstruction and establishing vegetation. For US post-SMCRA coal mines, such vegetation establishment is usually vigorous and rapid because of legal requirements, creating a pattern of vegetation loss and re-growth that is characteristic of reclaimed mines, and which we hypothesized could be used to differentiate mine sites from other landscape disturbances. Such sequential vegetation changes are uniquely represented by the VI change pattern (or the VI trajectory) constructed from a multiple-year Landsat sequence. The spectral trajectory of a mine shows a dramatic change at the onset of mining due to vegetation and soil removal, a condition that remains in place for the mining period, and is followed by vegetation recovery in the reclamation and post-reclamation phase (Figure 4.3).

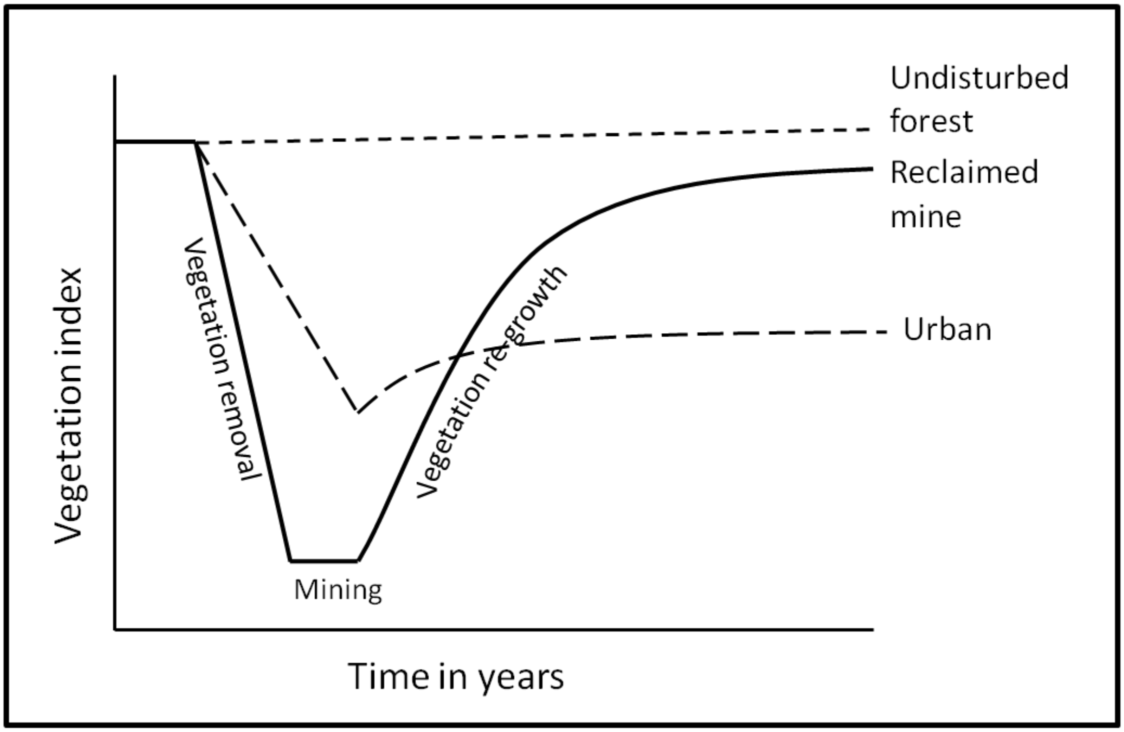

Figure 4.3. Hypothetical trajectories of undisturbed forests, reclaimed mines and urban disturbances.

We conducted preliminary analyses to identify three diagnostic spectral components of trajectories produced by reclaimed coal mines (Figure 4.4), which are:

- *Disturbance minimum*: This is the minimum value reached by the VI trajectory during the period of mining. This minimum value is lower than minima of less drastic forest disturbances such as fire and forest harvest that do not fully remove biomass and soil. We hypothesized that mining disturbance minima, on average, will be lower than urban disturbance minima because all mining disturbances but only some urban disturbances cause total land clearing.

- *Recovery slope*: After reaching a minimum, the VI trajectory increases in response to the reclamation activities which stimulate rapid vegetation development. We hypothesized that the slope of the recovery trajectory can be used to discriminate mining from post-disturbance urban activities, expecting the mining recovery trajectory to have steeper slopes due to high rates of vegetation regrowth that result from focused planting and fertilizing efforts in the reclamation period. Most urban development, road construction and similar disturbances were expected to exhibit recovery trajectories with less rapid increases for two reasons: (1) often, only a portion of such disturbances are revegetated, and (2) such revegetated areas are often managed to limit vegetation growth.
- *Recovery maximum*: Because vegetation typically develops rapidly, a diagnostic maximum value is reached at the end of a defined recovery period. We refer to this as the recovery maximum. Both the recovery slope and the recovery maximum are computed over a pre-specified recovery period. We hypothesized that, like the recovery slope, the recovery maximum will be greater for mined areas than for urban and related disturbances for similar reasons.

In order to operationalize these concepts, we developed disturbance/ recovery trajectories for several case-study coal mines and other disturbances and heuristically determined that a seven-year recovery period would be diagnostic for surface coal mine detection. Since our chronosequence has two missing years, seven years actually refer to seven consecutive images. Assessing the recovery trajectories within a defined time frame was necessary for comparable analysis of mining disturbances occurring at various points in the chronosequence.

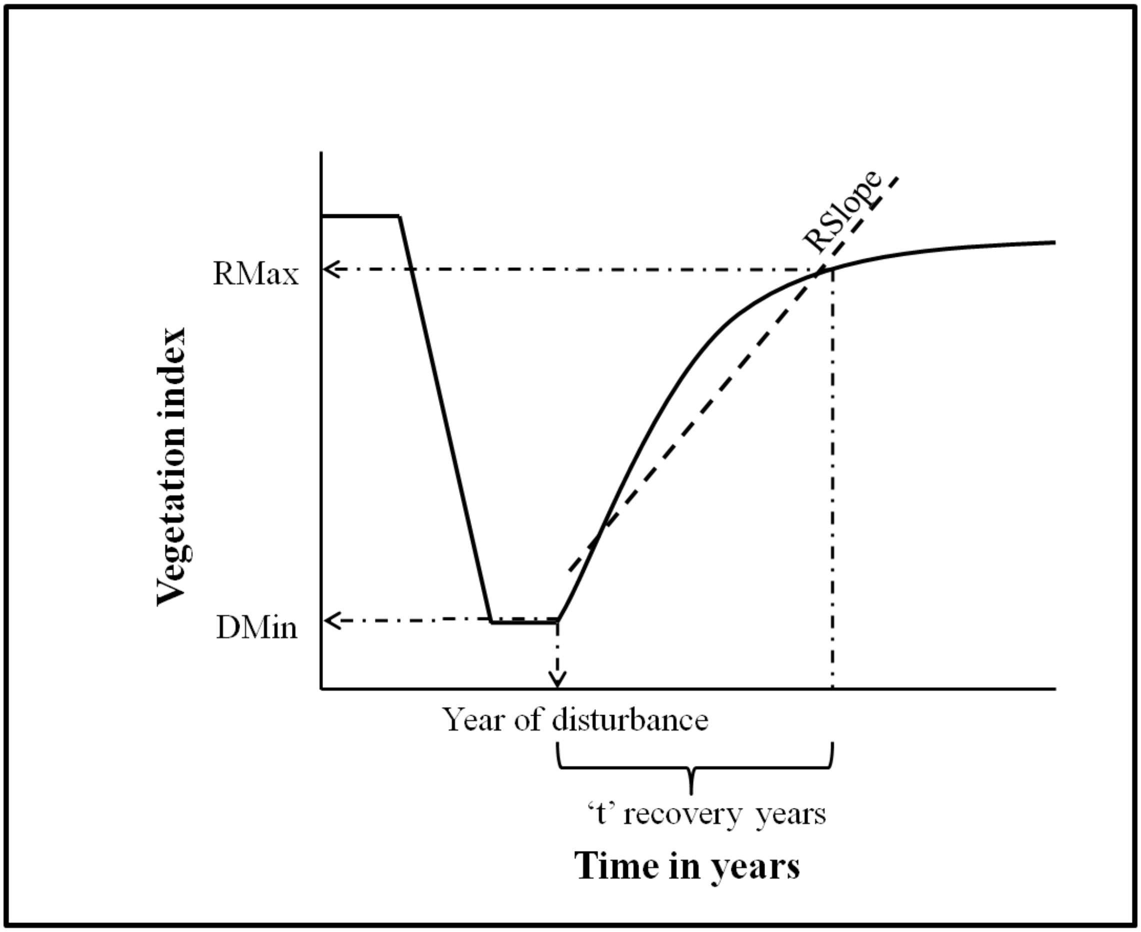

Figure 4.4. Disturbance/recovery parameters in a hypothetical mining trajectory. *DMin* stands for disturbance minimum, *RMax* for recovery maximum, and *RSlope* for recovery slope, which collectively constitute the disturbance/recovery parameters. *RSlope* and *RMax* are computed for pre-specified 't' years, which is 7 years for the present study. The mining period may be for one or multiple years, and *DMin* may or may not occur at the end of a multiple-year pre-reclamation mining period, as represented here.

4.3.6. Developing training and validation datasets

A total of 1262 points were selected for training and validation using ancillary data (Table 4.2). A stratified random sampling procedure was used to generate points with comparable representation in disturbed (mine and urban) and undisturbed classes. A mine layer created by manual digitization on DOQQ images was used to generate random mine points. Urban and forest points were obtained from the NLCD classification products from 1992 and 2001. Road points were obtained from the GIS road layer acquired from Virginia department of transportation (VDOT), and represent the road network as of 2001. Road points were merged with the urban points to create one ‘urban’ category. 650 of these (randomly selected) points were used for training purposes and 612 for validation. Since our algorithm was designed to detect mining disturbance that had a seven year recovery time, i.e., mining disturbance before 2001, care was taken to select training and validation points that did not include post-2001 disturbance. Hence we used only the DOQQ images that dated from 1992 to 1998 for different quads of our study area. VI values were computed for the training and validation points, as both pixels and objects. If an object contained a training or validation point, it received that point’s label.

4.3.7. Applying the classification algorithm

Step 1: Potential mining disturbance delineation

Disturbance of a vegetated landscape, by mining or by urban development, is initiated as a loss of vegetation. Thus, initial disturbances can be expected to have a VI value lower than the forests. Mining disturbances generally result in total or near-total vegetation loss within the mining footprint, whereas urban disturbances may cause either total or partial loss within the development footprint. Therefore, as preliminary separation of potential mining disturbances from other points, we identified VI thresholds below which all cases can be considered as potential mining disturbances.

Threshold identification: For each of the three VIs, threshold values were identified using 200 random training points with equal representation in mined and unmined (forest and urban) categories. For these points, the VI values were extracted for all years in the chronosequence and the minimum value (VI minimum) calculated. These points were subjected to binary recursive splitting in CART (vs.6, Salford Systems, California, USA), using the VI minimum as the only predictor variable. The node of best split (spilt which identified more than 90% of the data as mining disturbed) was identified as the thresholding value. A threshold for each VI was generated (Table 4.3) and applied for both pixels and objects.

Disturbance identification and parameters: An automated mapping approach was developed to detect disturbance within cloud-free portions of the multitemporal image stack (Figure 4.5). Two disturbance detection algorithms, one each for pixels and objects, were implemented in FORTRAN 95. Each applied an identical logic – to identify image components (pixels or objects) where the minimum value was lower than or equal to the threshold, identified as above. The cases that met the threshold criteria were labeled 'disturbed' and those that did not as 'low/no disturbance', a class that included both undisturbed forests and minor disturbances that caused VI values to decline lower than those of the undisturbed forests but not to levels characteristic of mining. For all disturbed pixels/objects, four disturbance/recovery parameters were reported:

a) Year of lowest value (year of disturbance),
b) Disturbance minimum,
c) Recovery slope (least squares estimate) for seven years after disturbance, and
d) Recovery maximum.

These disturbance/recovery parameters were output as four bands of a composite image. 'Low/no disturbance' points had zero values for all parameters. For disturbed points that did not have a seven year recovery time (labeled "post-2001 disturbance"), the algorithms reported the year of disturbance, the disturbance minimum, and zeros for the recovery slope and recovery maximum values. The classes identified by this step were 'disturbed', and 'low/no disturbance'.

Step 2: Recovery characterization

Disturbance/recovery parameters of training pixels and objects, identified as described above, were used as input in this step. Using these parameters, CART was used to separate the disturbed class into mined and urban classes. Separate models were built for each VI's pixels and objects. The models were built to process the training data using three of the disturbance parameters: the disturbance minimum, the recovery slope and the recovery maximum. Then, the models were applied on the algorithms' outputs for the whole image/objects (disturbed pixels and objects) to obtain images with further separation into mined and urban classes.

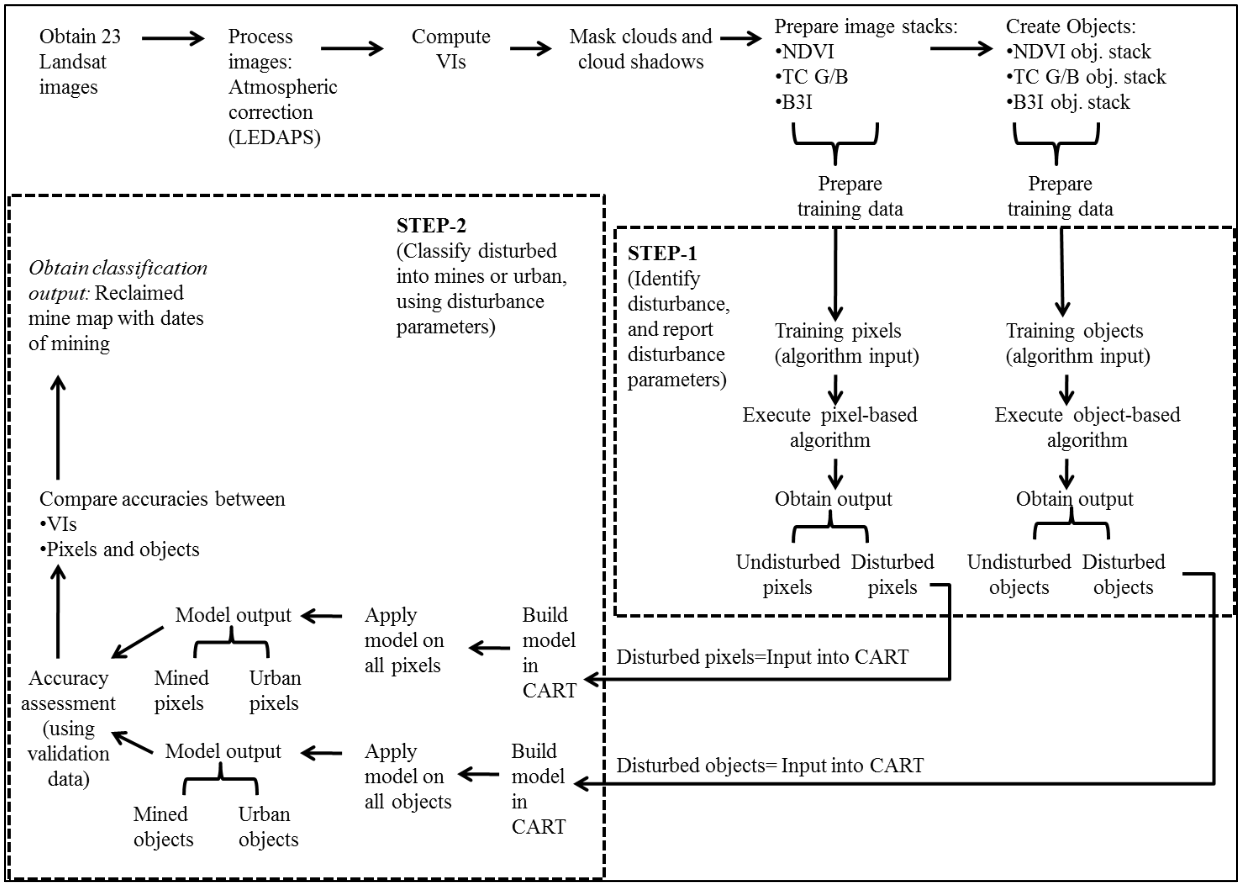

Figure 4.5. Flowchart of the mine land identification process. VI: Vegetation index, NDVI: Normalized difference vegetation index, TC G/B: Tasseled cap greenness/brightness index, and B3I: Band 3 inverse.

4.3.8. Post-2001 disturbance identification

The first band of the summary image (year of disturbance) was reclassified in ArcMap^{TM} (v9.3.1, ESRI, Redlands, California, USD); values of 0 were classified as forest, 1 to 16 as disturbance and 17 to 23 as post-2001 disturbance. The last category represented cases that did not have the seven years of recovery time necessary for mine identification. This reclassified image was merged with the CART classified image. The final classified image had the following categories: forest, mine, urban and post-2001 disturbance. It should be recognized that the urban category so defined is non-inclusive, meaning certain urban landuses (such as those where disturbance occurred prior to 1984 and had post 1984 VIs greater that mining disturbance threshold) may have been classified as "low/no disturbance". We do not consider this lack of precision as a problem because our goal is to identify mined and reclaimed areas. The years of disturbance, 1 to 16 of the first band were reclassified as 1984 sequentially to 2001 and labeled as the years of mining disturbance. This was merged with the mining area map to generate a year of disturbance map for the mined areas.

Potential mining disturbances occurring prior to 1984 were also identified if their sub-threshold disturbance signal persisted. As one example, consider a mine that was mined and reclaimed prior to 1984. This mine will have recovering vegetation post-1984. If the VI of recovering vegetation was low enough to fall below the disturbance threshold, then this mine would be identified as such. In this case since the lowest value would be found in the very first year of the sequence, the year of mining would be labeled as 1984 even though it could have been some years prior.

4.3.9. Validation and accuracy assessment

The classification results were assessed for accuracy by using the validation dataset. The post-2001 disturbance class was excluded from accuracy assessment because it did not possess characteristics to enable classification using the disturbance/recovery trajectory algorithm. Accuracy assessments of the six datasets (pixels and objects for each of 3 VIs) were done in ERDAS Imagine (v. 9.3, Leica Geosystems Inc.). For each of the six datasets, the 612 validation points were used to create a confusion matrix, and accuracy measures were computed according to Story and Congalton (1986) and Czaplewski and Patterson (2003). McNemar's test (Greenfield et al. 2009) was performed to assess the statistical significance of pairwise accuracy comparisons.

4.4. Results

4.4.1. Training data trajectories

Analyses of the training trajectories revealed that the mines' disturbance minima tended to be lower, and the recovery slopes and the recovery maxima higher, than the corresponding parameters for the urban class, as anticipated (Figure 4.6). This finding supports the hypothesis that the mining trajectory and its component parameters can be used to discriminate mining from other disturbance forms. Mined and urban distributions overlapped for all the three parameters, i.e., none of these parameters were sufficient, if used alone, for a classification with maximum accuracy. The disturbance minima exhibited the least and recovery slope the most separation between the two disturbance classes, and the B3I disturbance minima, on average, were not indicative of mining vs. urban differences. Hence we applied the three diagnostic/recovery parameters in combination as a means of separating reclaimed coal mines from non-mines.

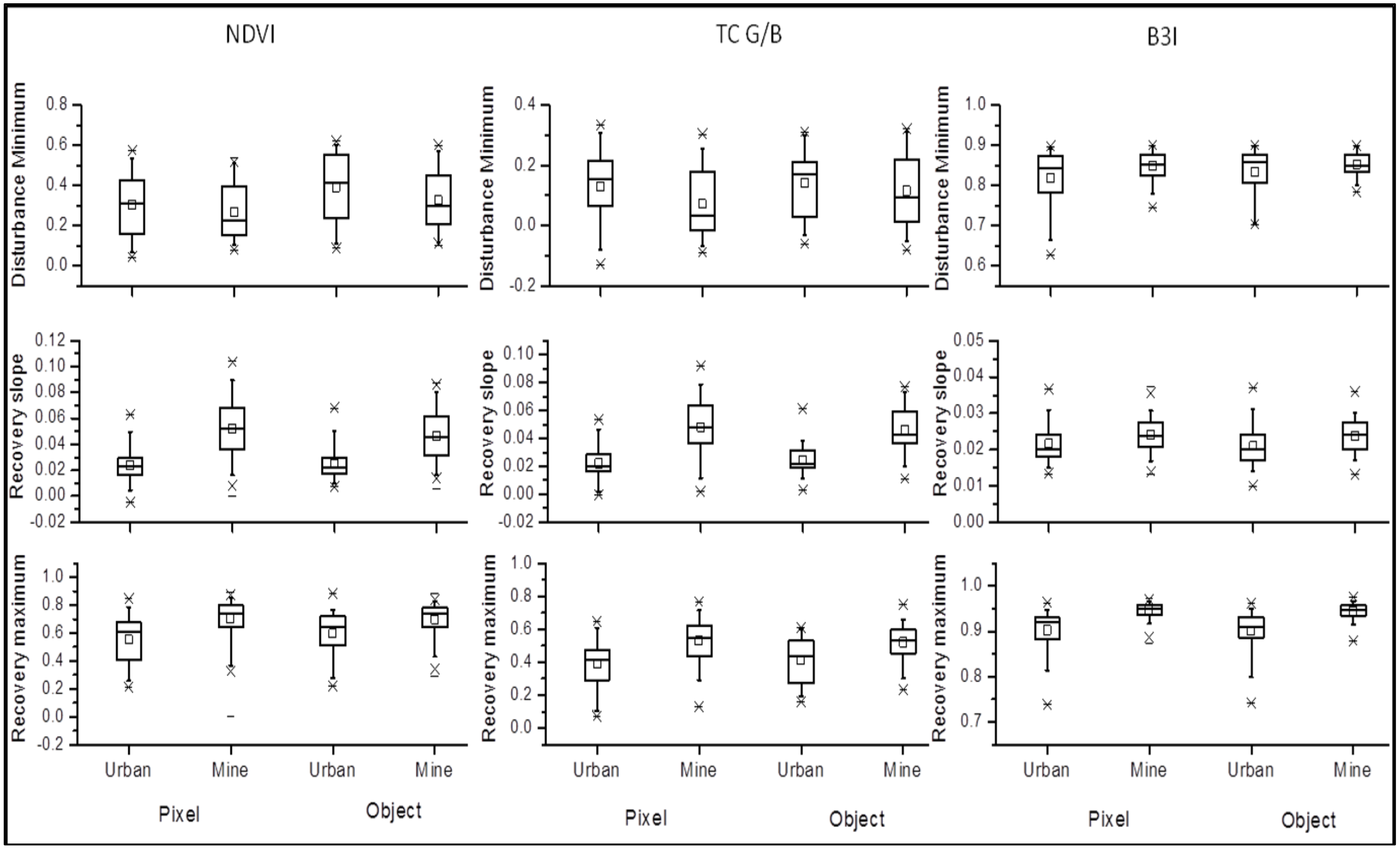

Figure 4.6. Comparison of parameter values of mine and urban categories, computed from training data for the three VIs and for pixels and objects. Box plots represent the 25th and 75th percentiles, and medians shown by the line; the whiskers range from 5th to the 95th percentile, while the small open boxes represent means.

Mining trajectories for pixels and objects were compared. Pixel-based recovery trajectories within the 7-year diagnostic period exhibited greater variance from the recovery slope than object-based trajectories (Figure 4.7). There is a high level of spatial variability of soil and vegetation characteristics within coal mine sites. Given that the image georectification is not 100% accurate, such spatial variability can affect interannual pixel-based trajectories to a greater extent than objects due to inconsistency of pixel registration within the image stack. Objects were less vulnerable to such inconsistencies since they represent the mean reflectance of all pixels within the object boundary. However, object trajectories, though generally smoother, were not free from fluctuations, likely reflecting interannual differences in image characteristics (time of day, atmospheric conditions, etc.) that were not fully normalized by the image processing algorithms. Climatic and phenological variations among years are other likely contributors to fluctuations.

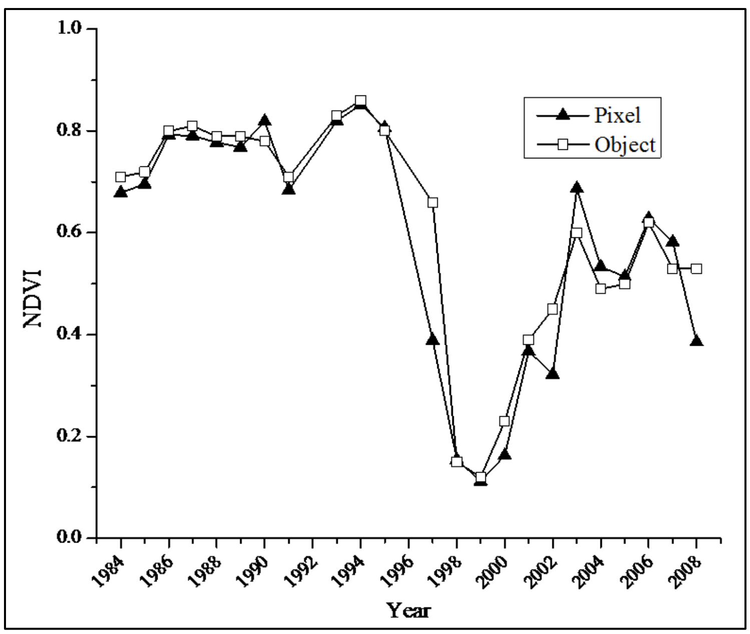

Figure 4.7. Comparison of NDVI trajectories for a reclaimed mine pixel and the object encompassing that pixel. The object trajectory reduces variance and more closely approximates the idealized mining recovery trajectory than the pixel recovery trajectory.

4.4.2. Classification Accuracy

The two step classification procedure resulted in pixel-based and object-based classification maps for each of the three VIs. A visual assessment of the output maps was conducted as the first step of the result assessment process. This qualitative assessment revealed that the NDVI and TC G/B pixel- and object-based maps are reasonable representations of on-the-ground conditions, This is evidenced by, in part, a 2003 NAIP image showing relatively accurate delineation of reclaimed mined areas (Figure 4.8). The object-based maps showed more internal consistency by reducing the salt-and-pepper effect within homogeneous classes as exhibited by the pixel based output. The TC G/B object-based map was superior to the NDVI object-based map in one sense, since there was less confusion between reclaimed mines and the urban class. However, the TC G/B classifications overestimated the occurrence of post-2001 disturbances, because the 2002 image, the only Landsat 7 ETM+ image, had the highest average TC brightness values. This caused frequent misclassifications due to resulting low TC G/B ratios for the year 2002. B3I maps were found to be quite unsatisfactory, as they did not correctly classify several mines and as a result significantly underestimated the occurrence of reclaimed mines.

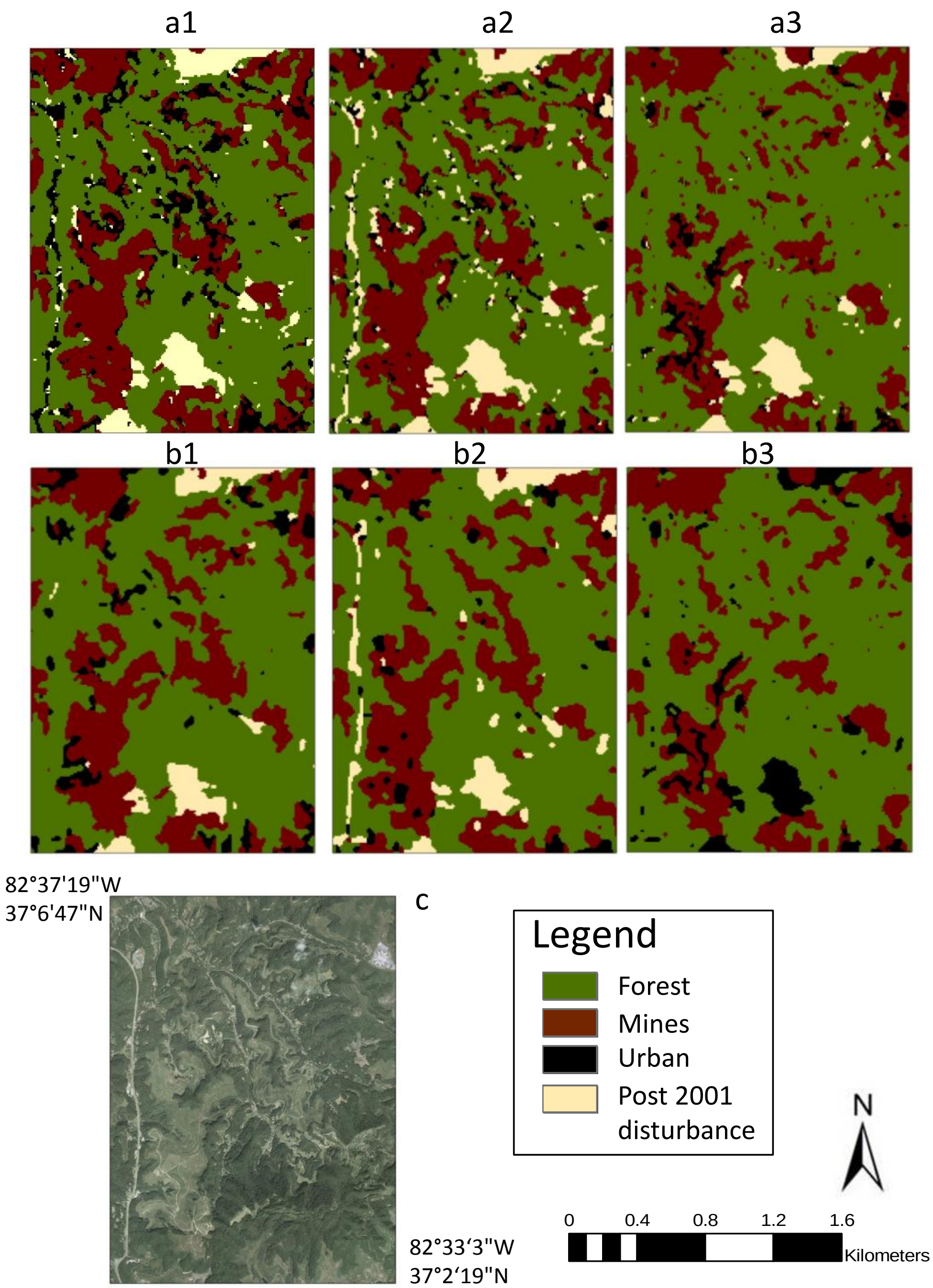

Figure 4.8. Classified landcover maps from: *(a1)* NDVI-pixel, *(a2)* TC G/B-pixel, *(a3)* B3I-pixel, *(b1)* NDVI-object, *(b2)* TC G/B-object and *(b3)* B3I-object. The NAIP 2003 image *(c)* is shown as a reference.

Accuracy assessment of the classified images revealed that objects outperformed the pixels for all three indices (Table 4.4). Objects are contiguous groups of pixels with similar spectral values, and the object reflectance is the average of the reflectances of pixels within each object. As such, objects are less impacted by the spatial variability within landcover types. Moreover, objects are more realistic in the mining context than pixels, since mining occurs over a large area contemporaneously. Object based TC-G/B classification had the highest accuracy (89.1%), and was closely followed by the object-based NDVI classification (87.9%). For the pixel-based classification, NDVI was slightly more accurate (87.3%) than the TC-G/B (86.3%). As had been observed visually, the B3I classification performed poorly for both pixels and objects.

Table 4.4. Calculation of mine vs. non-mine accuracies for the 612 validation points.

VI	**Correctly classified mine**	**Correctly classified non-mine**	**Overall accuracy**	**User's accuracy (mines)**	**Producer's accuracy (mines)**
NDVI (pixel)	147	387	87.3%	87.5%	72.1%
TCG/B (pixel)	133	395	86.3%	91.1%	65.2%
B3I (pixel)	126	349	77.6%	68.1%	61.7%
NDVI (object)	155	383	87.9%	86.1%	75.9%
TCG/B (object)	160	385	89.1%	87.4%	78.4%
B3I (object)	122	370	80.4%	76.2%	59.8%

Analysis of the error matrix of the best performing classification, object-based TC G/B classification, showed that there is some confusion between the urban and mined categories (Table 4.5). These points of confusion were investigated using the DOQQ and the 2003 and 2008 leaf-on NAIP photos. The investigation revealed that several misclassified objects were situated in mining-impacted areas that have not been reclaimed with vegetation. Such areas include, mine roads, active tailing/refuse disposal sites, mine operations' building sites, and equipment maintenance locations. In these cases, little post mining vegetation growth has occurred by design due to these land uses; thus, such areas had recovery slopes and recovery maxima comparable to urban areas. The remaining few misclassifications of this type occurred where poor vegetation recovery was evident in the aerial image, or where there was renewed disturbance within the 7-year recovery window.

Table 4.5. Error matrix of object-based classification of TC G/B index.

	Reference data				
Classified Data	Forest	Mine	Urban	Classified total	User's accuracy
Forest	192	12	47	251	76.5%
Mine	6	160	17	183	87.4%
Urban	3	32	143	178	80.3%
Reference total	201	204	207	612	
Producer's accuracy	95.5%	78.4%	69.0%		

Results of the McNemar's (Table 4.6) test showed that at the 90% (z =1.645) confidence level, objects were significantly more accurate than pixels for TC G/B and B3I, but not for NDVI.

Table 4.6. Matrix of *z* values obtained from McNemar's test representing the statistical significance of differences in accuracies between each of the fifteen comparisons. Comparisons significant at the 90% confidence level are shown with an asterisk.

		PIXELS			**OBJECTS**		
		NDVI	TC G/B	B3I	NDVI	TC G/B	B3I
	NDVI	0					
PIXELS	TC G/B	1.06	0				
	B3I	5.93*	5.27*	0			
	NDVI	0.57	1.25	6.09*	0		
OBJECTS	TC G/B	1.31	2.14*	6.23*	0.83	0	
	B3I	4.75*	4.18*	1.86	4.79*	5.27*	0

* $0.05 \leq p < 0.10$

The disturbance-year map (Figure 4.9) identified reclaimed mines and provided information on the last date of mining/start of vegetation recovery for each mined area.

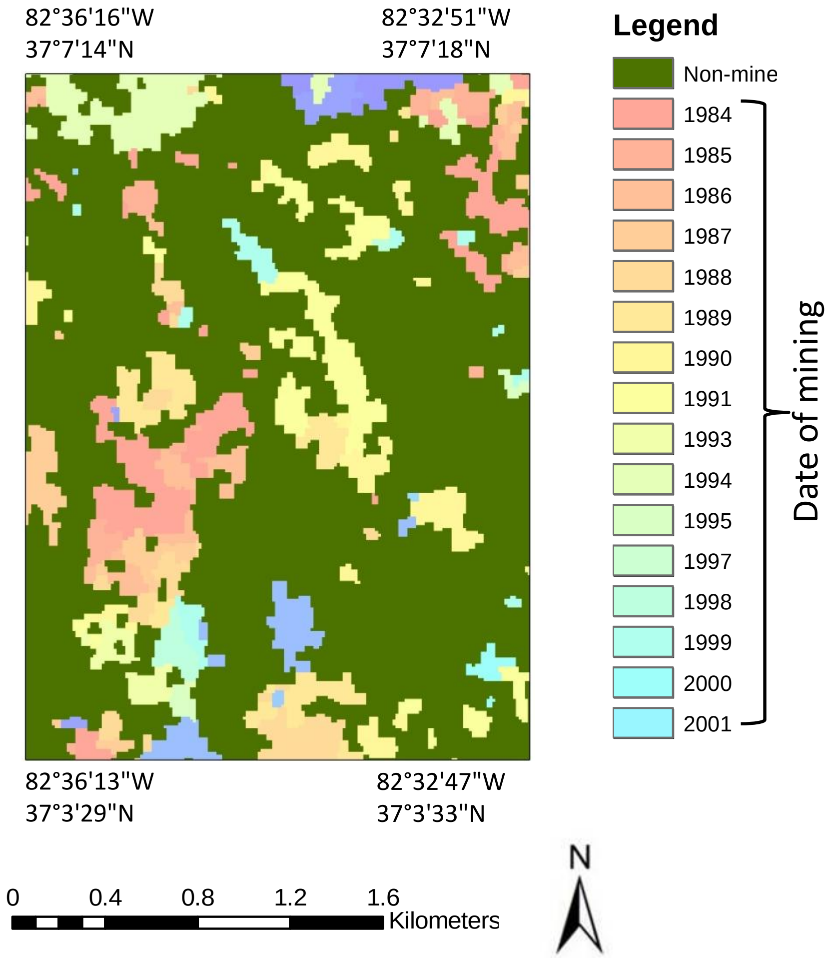

Figure 4.9. Disturbance-year map of the reclaimed mines, a subset of the TC G/B object-based classification.

4.5. Discussion

Multitemporal trajectory analyses are well-suited to characterization of both short-duration landscape processes, such as forest disturbance, and longer-term, slowly evolving processes such as ecosystem recovery following disturbance (Coppin and Bauer 1994; Guild et al. 2004; Kennedy et al. 2010; Lawrence and Ripple 1999; Schroeder et al. 2007). We applied and adapted multitemporal analysis methods to identify mines that were mined and reclaimed within the 1984-2001 time-span, using a dense chronological stack of Landsat images. The identification was a two-step process, involving a disturbance detection algorithm followed by a CART-based classification of disturbances as mined or urban. Classification was performed separately for three VIs on both pixels and objects and the classification accuracies were compared. The results revealed that the objects were significantly better suited to the task of identifying mining areas for TC G/B and B3I, likely because they integrate within-class spatial variability. Studies comparing pixel- and object-based approaches have found the former to be sensitive to noise and often lacking spatial consistency (Soille 2003), sometimes giving rise to "salt-and-pepper effect" in the change detection products, which is considerably eliminated by an object-based approach (Blaschke and Strobl 2001).

Like other multitemporal change-detection approaches, our method relies on precise geometric registration, radiometric normalization and cloud screening to enable intra-sequence image analysis. Viedma *et al*. (1997) and Kennedy *et al*. (2010) identified imprecise image co-registration as a source of error in pixel-based trajectory analysis, while Townshend et al. (1992) has demonstrated the effects of misregistration in change detection products developed from MODIS NDVI. Objects are less vulnerable to the inconsistencies from pixel-misregistration. Kennedy *et al*. (2007) suggested that patch-average metrics (object-based metric) could be used in future studies as an alternative to pixel-based metrics since they allow for accurate detection of subtle change effects by increasing the signal-to-noise ratio. Our study found similar results with object-based detection being superior to the pixel-based method for two of the three indices tested. Among the object-based VIs, TC G/B was more accurate than either NDVI or B3I. This may be due to explicit inclusion of background soil brightness effects in the TC G/B index, but further research will be needed to test this conjecture. The pixel-based classification, particularly the NDVI-pixel has been observed to detect roads better than the objects, based on the fact that such are often linear and have areas that are better justified by pixels than objects.

4.5.1. Trajectory Components

The analysis found that, as hypothesized, disturbance minima tended to be lower and recovery slopes and maxima higher for mining than for other disturbances within the better performing VIs. However, there is considerable in-class variance for each of these disturbance/recovery parameters, so no single parameter is diagnostic when used alone. Thus, we found derivation of multiple parameters from the spectral change curve aids analysis and interpretation of mining-caused forested landscape change, a result that is consistent with the multiple-parameter approach to trajectory interpretation applied by Kennedy *et al*. (2007). The fact that recovery trajectories achieved sufficient uniformity to aid our interpretations may have occurred as a result of US coal-mine reclamation law requirements for rapid initial revegetation with fast-growing and thick grasses (Angel et al. 2005). Thus, whether our approach could be applied or adapted successfully in other mining areas of the world is a potential area for future investigation.

Our study revealed that recovery trajectories exhibit high variance around the slope, likely due to variations in image characteristics (solar brightness, atmospheric conditions, and seasonal provenance) and interannual climatic influences on vegetation. A likely improvement would result from uncoupling the effects of vegetation phenology from the original vegetation signal. Huang *et al*. (2010) normalized these seasonal variations by computing forest z-scores (FZ) using mean and standard deviation of spectral values for forested samples for a single spectral band and integrated forest z-scores (IFZ), by integrating FZ scores for all spectral bands in a multispectral image. However, remnant phenological effects caused by a lack of temporal coherence between the reference and target class can still be present. Schroeder *et al*. (2007) used a date-invariant regression to construct the fitted trajectory curve and found that phenology effects did not prevent the forest regrowth curves from capturing the pixel's original vegetation response. Kennedy *et al*. (2010), in their LandTrendr work, used a de-spiking algorithm to dampen the noise-induced spikes before the trajectory-fitting exercise. This algorithm removed spikes where the spectral values before and after the spike were similar, 'similarity' being determined by user-specified control values. Another reason for the variability could be that the grasses, which are predominant during the initial growing stage, are vulnerable to weather fluctuations and therefore show immediate changes in vegetative cover. This variability will likely decrease with time as the trees start growing and developing canopies, since trees are less vulnerable to subtle climatic changes. The seasonal variance in the Landsat images can also contribute to the variability. Although the best-performing VI achieved ~90% classification accuracy, there was some residual confusion between the mine and the urban classes. A brief analysis was carried out to test if the misclassified disturbance objects were isolated within correctly classified object clumps. The results revealed that about 91% of the incorrectly labeled mines (mines labeled as urban) were nested within areas that had been correctly classified as mines. This suggests that such incorrectly classified mined objects can be easily identified and corrected using automated methods such as contextual object-oriented classification. Agricultural areas were not considered separately in the classification owing to (1) their low level of representation in the study area, and (2) their overlap with mined areas (since grazing and hay production are often conducted on reclaimed coal mines within the study area). However, several small areas of agricultural land were present within the non-coalfield segment of the study area. Retrospective analysis revealed that these were classified as urban since their vegetation growth pattern resembles that of the urban category.

Whereas several prior multitemporal Landsat interpretation studies have been conducted in the Pacific northwest (i.e., Lawrence and Ripple, 1999; Kennedy *et al*., 2007; Schroeder *et al*., 2007; Song *et al*., 2007), our study demonstrates that such techniques can have utility when applied over forested areas with mixed land uses in the eastern US. Forested systems in both areas have structural and spectral similarities, a fact that aids common application. In the eastern US coalfields, however, non-mining landscape disturbances are intermingled with mining activity, but our approach succeeded in discriminating mining areas. Cloud cover proved to be problematic within our eastern US study area, due to its frequency during the leaf-on season. Thus, we conducted analysis only within the cloud free areas of our image stack, which demonstrated the utility of multitemporal analysis to coal mine identification but failed to achieve full area characterization. Kennedy *et al*. (2010) dealt with cloud-cover issues using both mosaic and bridging approaches. Huang *et al*. (2010) temporally interpolated using the nearest non-cloud observations, before and after the cloud-contaminated year. Such methods can be applied in future studies to achieve full area characterization. A drawback to our approach was the time intensive manual cloud and cloud-shadow screening. The process could be expedited by inclusion of automated methods such as those developed in the Huang et al.(2010) study and used in the Vegetation Change Tracker (VCT) algorithm (Huang et al. 2010). They found that cloud-covered pixels typically occur on the lower right hand corner of a temperature-red band spectral scatter plot (due to their high reflectivity but low temperature) and used a cloud-threshold to separate such pixels. In our experience, cloud shadows are more complicated to identify, particularly in mountainous terrain, due to their spectral similarity with the ridge shadows. Huang *et al*. (2010) used cloud height, normal lapse rate computations and solar illumination geometry to identify cloud shadows. Such automated approaches of identifying clouds and cloud shadows will be important to operational implementations of this or similar protocols.

While our study found ecosystem recovery profiles essential to discrimination of coal-mined areas from other forest disturbances, it leaves questions concerning the nature of the ecosystem recovery processes those profiles represent. It is clear that forested ecosystems recover very slowly on coal mined sites that are not properly restored for that purpose, in large part due to the nature of the reclamation processes that are commonly employed (Angel 2005; Simmons et al. 2008). It is also clear that woody vegetation sometimes encroaches on such sites, when unmanaged over time. However, such encroachment varies significantly both among and within individual mine sites (Skousen et al. 1994; 2006); encroaching woody vegetation may be of species not characteristic of the native forest (Zipper *et al*., 2007); and such encroachment increases costs of post-reclamation rehabilitation (Burger and Zipper 2010). Thus, further development and application of remote sensing methods to characterize the nature and status of ecosystem recovery processes on these previously mined but currently unused areas, as others have demonstrated is possible with multitemporal analyses of forest disturbances in the Pacific northwest (e.g., Lawrence and Ripple, 1999; Song *et al*., 2007), would aid development of management strategies for these extensive land areas over the longer term.

4.6. Conclusion

The disturbance/recovery trajectory approach has proven to be an efficient and effective mechanism for distinguishing the reclaimed coal mines from forests and other sources of disturbance in cloud-free areas. The predominant source of classification errors were segments of mined areas under management regimes that prevented vegetation re-establishment; hence, these areas did not have recovery characteristics that proved diagnostic for the majority of mined areas. Because most of these urban misclassifications were nested within predominantly mined areas, automated methods could be applied to assist time-efficient manual identification during an error-checking process in broad-scale applications. Development of cloud-bridging algorithms will enable more accurate and time-effective applications.

Landsat images with their temporally rich archive, spatial and spectral scale suited to the scale of land management, easy availability of images and tailor made image processing routines, are well suited for trajectory analysis (Huang et al. 2009). Such analyses have been applied successfully by other researchers to detect and characterize non-mining forest disturbances and recoveries. Here, we have demonstrated that they can be applied to detect mining disturbances as well. In the Appalachian region of USA, detection of such disturbed areas would be necessary as a first step, in a comprehensive strategy for rehabilitation, management, and more effective utilization of such areas.

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Chapter 5 Estimating Woody Canopy Density on Appalachian Coalfield Landscapes Using Landsat Data.

5.1. Abstract

In the humid and predominantly forested landscapes of the eastern US, woody canopy cover is an indicator of ecological status. The USDA Forest Service (USFS) has initiated an effort to estimate tree canopy cover for the US using Landsat imagery and digital terrain data as part of the 2011 National Land Cover Database (NLCD) program. This study evaluated performance of a woody canopy cover estimation method, based on the 2011 NCLD effort, on both mined and non-mined areas of Appalachian landscapes. Reference canopy cover was created by photo-interpretation of 2,700 m^2 photo-plots (equivalent to 9 Landsat pixels) on 2008 leaf-on aerial photography from the National Agriculture Imagery Program (NAIP). Sampled photo-plots were classified as mined, non-mined and "mixed" (part mined, part non-mined). Potential explanatory variables included raw and derived bands from leaf-on and leaf-off Landsat scenes plus terrain descriptors. The model developed to estimate canopy cover for mines (R^2 = 0.78, Adj. R^2 = 0.77, RMSE = 16%) is more robust than the models developed for non-mines, mixed, and all areas combined. Two spectral variables (leaf-on and leaf-off NDVI) and two terrain variables (the sine and cosine of terrain aspect) contributed to both the mined and non-mined models, but other variables, mostly spectral, were unique to models for each land cover class. This study has shown the strong potential for estimation of woody canopy cover in previously mined areas using Landsat imagery and digital terrain data.

5.2. Introduction

Eastern United States of America contains more than 600,000 hectares of lands mined for coal and reclaimed to satisfy the requirements of a federal law, the Surface Mining Control and Reclamation Act (SMCRA); additional areas were mined and reclaimed prior to SMCRA. Since most of these areas are in an unmanaged condition, varying reclamation practices and recovery periods have resulted in a variety of landcovers. Depending on the time since reclamation and the revegetation choice at that time, the lands were initially reclaimed to establish various land covers, including "hayland-pastures", comprised of herbaceous plants suitable for use as forages, and "forests" of various types and management intensities.

The extent of tree canopy cover is an essential indicator of lands' ecological status, regardless of mining condition. On unmanaged mined lands in Appalachia, the extent of tree cover can be seen as an ecosystem development indicator. Knowledge of woody canopy, although potentially comprised of native or non-native species on unmanaged mined lands, can provide insight into these lands' vegetative status and forest succession potentials. Information on these lands' woody canopy can aid development of policies concerning use and management of these lands. Unfortunately, such information is unavailable from publically accessible data bases, therefore hindering the process of decision making.

Remote sensing multispectral imagery has been widely used for large area landscape characterization studies (Homer et al. 2004; Lunetta 1998; Vogelmann et al. 2001). Imagery from the Landsat satellites is especially useful for such studies, owing to its unmatched historical archive, no-cost availability, grain size matching scale of land management, and spectral and temporal resolution (Cohen and Goward 2004; Huang et al. 2009; Kennedy et al. 2010). In efforts to interpret multispectral satellite data to characterize canopy cover, past researchers have used several techniques, including spectral mixture analysis (Elmore *et al.*, 2000), linear mixture models (Adams et al. 1995;

Defries et al. 2000), linear (Iverson et al. 1989; Zhu and Evans 1994) and non-linear regressions (Huang and Townshend 2003), and regression tree techniques (Huang et al. 2001; Pantaleoni et al. 2009). In this paper, we apply one of these methods, linear regression, to estimate tree canopy cover on reclaimed mines. We have selected this approach because it is relatively simple and easy to implement and has potential for future operational uses over large extents such as the entire Appalachian coal fields.

Past studies have used Normalized Difference Vegetation Index, NDVI (Rouse 1973) to successfully estimate vegetation cover (Gamon et al. 1995; Isabirye et al. 2008; Roderick et al. 1999). Some studies have also used tasseled cap (TC) transformation components (Crist and Cicone 1984) as indicators of forest structure and its change (Franklin et al. 2002; Schroeder et al. 2007; Song et al. 2007). Others yet have used Landsat spectral bands from leaf-on and leaf-off scenes as modeling inputs to represent vegetation characteristics (Huang et al. 2001).

The Multi-Resolution Land Characterization Consortium (MRLC) created a forest tree canopy density database for all 50 states of the US, as a part of the National Land Cover Database (NLCD) 2001 initiative, using several Landsat 5 and Landsat 7 images. The tree canopy density reference data were created by classification of 1m DOQQs; models developed from those data, and were extrapolated on the Landsat to estimate the tree canopy density per 30 m pixel. Tree canopy density was modeled using empirical relationships with the Landsat-derived metrics and regression tree techniques. The tree-canopy estimation model thus created was spatially extrapolated to produce tree canopy density maps for the US (Huang et al. 2001). This was made available as an independent product that quantifies spatial distributions of tree canopy as a continuous variable varying from 0 to 100 percent (Homer et al. 2004). In a preliminary error analysis, Homer et al (2004) reported mean absolute errors to rage from 6 to 17%. In a more formal wall-to-wall analyses for the conterminous United States, Greenfield et al (2010) reported significant differences between NLCD tree canopy estimates and photo-interpreted estimates. Several other studies (Greenfield et al. 2009; Homer et al. 2007; Walton 2008) have also demonstrated the underpredictive tendency of the NLCD canopy layer in different parts of the US.

In light of these shortcomings of the NLCD 2001 canopy cover product, there was need to re-estimate the tree canopy cover. A protocol was developed for five pilot study areas in US as a part of the NLCD 2011 effort. For the pilot study areas, response data was created by photo-interpretation (using NAIP 2008) of samples obtained from the Forest Inventory and Analysis National Program (FIA) sampling grid. The potential explanatory variables included spectral variables, obtained from Landsat leaf-on and leaf-off imagery, and terrain variables developed from National Elevation Dataset (NED) Digital Elevation Model (DEM); models were created using the Random forest(tm) algorithm (Breiman and Cutler), K nearest neighbor and support vector machines (Coulston et al. 2011; Jackson et al. 2010; Moisen et al. 2010; Tipton et al. 2010). The results in the pilot study area in Georgia showed that an R^2 of 0.83 was achieved using Random forest- based regression (Salford Systems Inc.). The preliminary reports of success from these studies encouraged us to apply these methods in an effort to estimate woody canopy cover for the southwestern Virginia area of the Appalachian coalfield, a landscape that has been extensively surface mined. Explicitly stated, our objectives for this study were:

- Evaluate the applicability of a protocol, similar to that created for tree canopy estimation as a part of NLCD 2011, over the extensively mined areas of southwestern Virginia.

- Determine if mined and non-mind areas represented in the study area can be modeled for canopy cover using a single model, or if use of separate models will improve estimation precision.

5.3. Methods

5.3.1. Study area

The study area is four counties of southwestern Virginia (Figure 5.1) which occur predominantly within the Appalachian coal fields. They have been mined since the 1800s, with widespread surface mining occurring since the 1960s. Most of the unmined areas are occupied by deciduous and/or mixed deciduous-coniferous forests. Other non-mining landuses include residential areas, roadways, and urban uses such as commercial and industrial development. Agriculture is not a major land use in the coalfield areas; and much of that which does occur is livestock grazing on reclaimed mines.

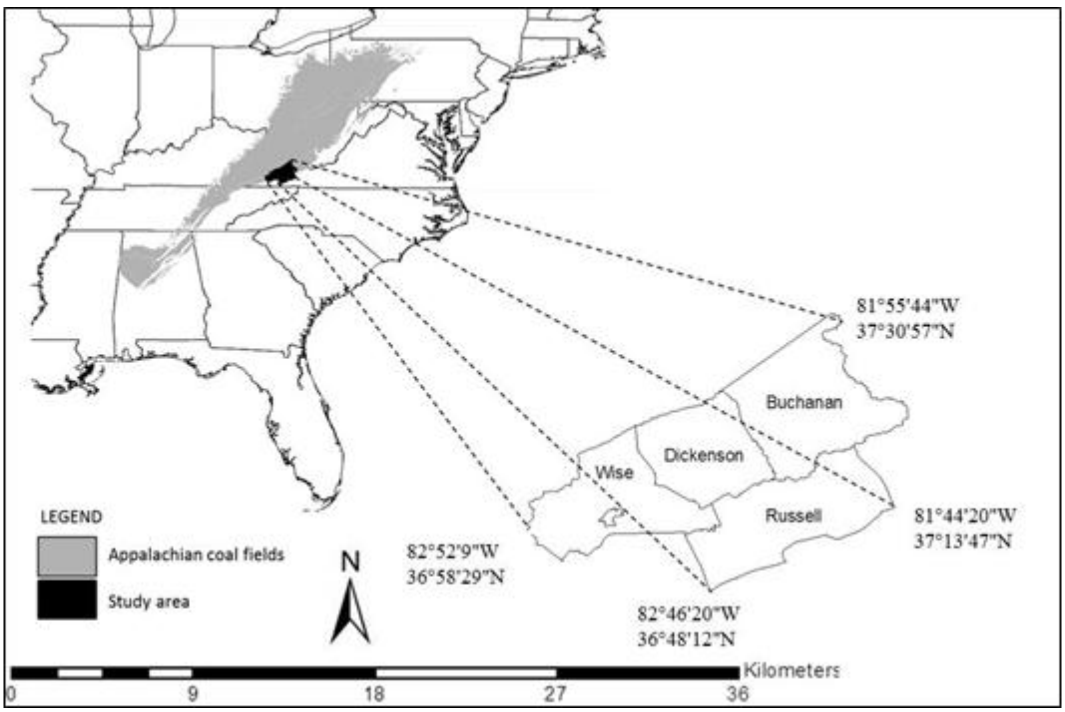


Figure 5.1. Study area comprising of coal mining counties: Wise, Dickenson, Buchanan and Russell, in southwestern Virginia. Figure based on Sen et al. (2011).

5.3.2. Pilot Study: evaluating NLCD (2001) tree canopy database for mined areas

A short exercise was carried out to test the accuracy of the NLCD tree canopy density estimates on the reclaimed mined lands. The NLCD tree canopy density data were downloaded from MRLC (2011) for the counties of Wise, Dickenson and Buchanan. Reclaimed mines within those counties were identified using methods described by (Sen et al. 2011). The NLCD 2001 tree canopy cover layer for those mined areas was then classified into five equal-density classes (0-20%, 20-40%, 40-60%, 60-80% and 80-100%) in ArcMap™ (ESRI, Redlands CA). Random points were identified within those areas using a stratified random sampling design. A vector grid of dimension 30x30 m^2 was created in ArcMap™ to mimic the Landsat pixel grid and overlaid on the sample layer. Using NAIP 2003 leaf-on photo, each potential sampling point was inspected to test if they met the following criteria:

a. Identical NLCD cover class in the surrounding eight cells.

b. Not located in shadows of adjacent forest canopies or mining landscape feature.

Sample points were selected if they met the above criteria. This activity resulted in 68 sample points.

Development of reference canopy cover: Reference points were created by manual digitization of the National Agricultural Imagery Program (NAIP) (USDA 2010) photos as employed by Pantaleoni et al. (2009). A leaf-on aerial image, coincident with 2001 NLCD product was needed for creation of reference points. The closest-in-time leaf-on option was NAIP 2003 which was downloaded for the counties of Wise, Dickenson and Buchanan. The sample points were overlaid on the NAIP. The 30m grid layer was overlaid on the sample points and the cells that contained the reference points were selected for woody canopy cover estimation. Each cell's boundary was digitized, canopies of all visible trees and shrubs wholly or partly within the cell boundary were digitized as polygons, and woody canopy polygon areas were summed. Then percent canopy density was calculated as:

$$\text{Woody } canopy\ cover\ (\%)\ = \frac{Woody\ canopy\ area\ (m^2)}{Area\ of\ grid\ cell\ (900\ m^2)} x100 \qquad \text{Equation 5-1}$$

The NLCD (2001) tree density values were extracted for each sample point and compared to the (%) woody canopy values calculated from reference cells using linear regression analysis.

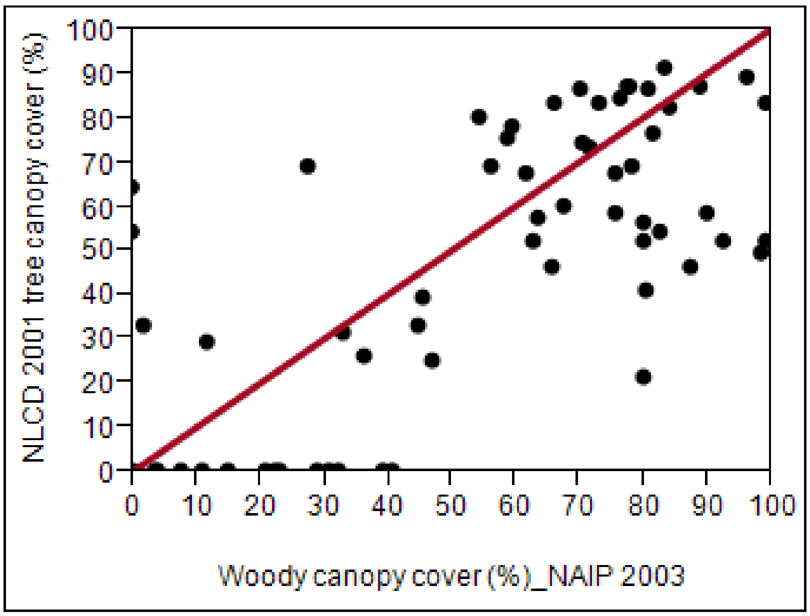


Figure 5.2. Estimates from NLCD (2001) percent tree canopy database plotted against canopy estimates derived from aerial photo interpretation. The red line shows the 1:1 relationship.

Results of NLCD evaluation: The NLCD 2001 canopy cover estimates when compared with the photo-interpreted samples (Figure 5.2) showed that there is severe under-estimation in both the low canopy density classes (0-20%: RMSE = 23.2, 20-40%: RMSE = 30) and also in the highest canopy class (80-100%: RMSE = 32.06). The underestimation was not as severe for the mid-canopy classes (40-60%: RMSE = 17.21, 60-80%: RMSE = 13.64). The underestimation in the low-canopy classes is particularly problematic, since sparse tree-canopy conditions occur commonly in mined areas. For most mined areas where NLCD reported zero woody canopy cover, the NAIP photos showed some degree of cover.

5.3.3. Woody canopy estimation

In light of the low accuracy of NLCD 2001 tree cover estimates, a new process was developed in cooperation with USDA Forest Service (USFS). Our method was based on a protocol evaluated by USFS for re-estimation of tree canopy as a part of their NLCD 2011 effort. We applied a method similar to their basic method to determine the feasibility of developing tree canopy estimating models over areas where mined lands constitute a significant fraction of the land-base. In this study woody canopy cover includes the entire arborescent vegetation group, without making distinctions between trees and shrubs large enough to be visible on the NAIP imagery, and without making distinctions between native and non-native woody species. Woody canopy density for this study is expressed as a decimal fraction ranging from 0 to 1.

Response variable

The response variable, the fraction of points covered by woody canopy or woody canopy density, was developed by photo-interpretation using leaf-on NAIP 2008 photo. The samples were obtained from the 4x intensified FIA National Program (FIA) sampling grid (Bechtold and Patterson 2005). The FIA sampling grid was developed using the EMAP sampling strategy (White et al., 1992) and overlaid on the study area. Each sample (photo-plot) consisted of 105 points (photo-points) which covered an area equivalent to 3x3 Landsat pixels. Each photo-point was labeled as tree or no-tree using an ArcMap™ extension, Canopy Cover, developed by USFS. Using the tree/no-tree labels from all points in a photo-plot, a woody canopy density was computed for each photo plot. Each photo-point was also labeled as mined or not mined. For most photo-plots, the mined vs. non-mined point identifications were made using NAIP 2008; however, photo-plots identified as unmined using the 2008 imagery were checked for mining status using older imagery (NAIPs from 2003 and 2005, and DOQQs from the mid-90s), and reclassified as mined if revealed by the older imagery. Each photo-plot was also labeled as "mined" or "non-mined" if all 105 points were of a similar status, and as "mixed" if it included both mined and non-mined photo-points. The central point became the representative point for the photo-plot and was assigned labels for woody canopy density and mined condition.

At the end of this exercise it was found that the mined category was represented only by 60 photo-plots, a number considered as insufficient for model development. Additional photo-plot were identified from a denser-9x sampling grid and added to the existing mined sample. For the 9x grid, only mined photo-plots were photo-interpreted. Judgment on the mined status of a photo-plot was made if the point occurred on a reclaimed mine, as shown by the underlying NAIP 2008 photo. Cross-checks with older NAIP photos were also conducted. The identified samples were photo-interpreted using the process similar to the 4x samples. All samples (4x and 9x mined) were combined for modeling purposes, resulting in 136 samples in mined, 145 in mixed, and 561 in non-mined categories. A "combined" group was also created to include all photoplots, 842 samples.

Figure 5.3. Photointerpretation techniques used in development of response variable on a a leaf-on NAIP 2008 photo background. Top left: the 4x samples. Bottom left shows a photo-plot with 105 photo-points, and the figure at the right shows the tree/no tree labelling using the Canopy Cover ArcMap extension. The photo-plot shown here belongs to mixed category.

Explanatory variables

Fifty four landscape variables were identified as potential explanatory variables for the woody canopy density estimation models. Terrain data, derived from the Virginia Base Mapping Program (VBMP) 2007 data (VITA 2010) were obtained from Virginia Department of Mines Minerals and Energy in the form of vector polylines representing 5m contours. The VBMP data were obtained for model development because they are recent and reflect topographic changes that may have occurred due to mining. Polylines were converted to 30 m raster using Spatial Analyst extension in ArcMap. From these raster layers, slope and aspect were calculated in ArcMap^{TM}. The Aspect was transformed into radians, and cosine and sine of aspect were computed from the transformed aspect layer.

Table 5.1. Variable class and variables types that were used in model development. For each variable type, focal mean and focal standard deviation were calculated from the pixel means within a 9-pixel window to generate the 54 variables.

Variable class	Variable types
DEM and DEM derivatives	Elevation
	Aspect
	Slope (percent)
	Cosine aspect
	Sine aspect
Landsat leaf-on (9/3/2008)	Spectral bands 1,2,3,4,5,7
	Temperature band
	NDVI
	TC band 1 (brightness)
	TC band 2 (greenness)
	TC band 3 (wetness)
Landsat leaf-off (1/25/2009)	Same as for leaf -on

Additional variables were developed using a leaf-on Landsat image from September 3rd, 2008 and a leaf-off image from January 25th, 2009. These cloud-free images were obtained from USGS as Level 1T, in a terrain corrected form. Radiometric and atmospheric corrections were performed using the LEDAPS algorithm (Masek et al. 2006) surface reflectance product. For each image, NDVI, and the three TC indices (band1, brightness; band2, greenness; band 3, wetness) were computed for each grid cell. For each model development data point, potential explanatory variables were computed as focal means and focal standard deviations (i.e. mean and standard deviation of the 3x3 pixel window) for spectral bands 1 to 7, including the brightness corrected temperature band (band 6) and the vegetation indices (table 5.1).

Variable selection

All variables were tested to check for multicollinearity. A non- parametric correlation coefficient (Spearman's rho) was calculated for all variable pairs. Variable pairs with rho > 0.8 were identified, and the member of that variable pair with less correlation with the dependent variable (woody canopy density) was eliminated. This exercise was performed separately for each model group (mines, non-mines, mixed, and combined). Next for each model group, a best subsets regression was performed in Minitab statistical software (v. 16, Minitab Inc., State College PA, USA) to identify the best possible subset of variables that could be used to construct an efficient woody canopy estimation model. Model selection criteria were: relatively high adjusted R^2 and Mallow's Cp ≤ (number of variables+1), while endeavoring to maintain lower number of variables for a parsimonious model. This procedure resulted in the selection of a best subset of potential explanatory variables for each model group.

Model development

A separate model was estimated for each model group using multiple regression procedures to estimate woody canopy as a function of explanatory variables selected as the best subset. For each model, plots of residuals versus predicted values, histograms and normal quantile plots (Q-Q plots) of residuals were used to examine the assumptions of normality and randomness of error. Outlier checks were conducted by examining the residuals, using twice the standard error of model (obtained from best subset results) as the threshold value and by inspecting the residual vs. predicted plots; outliers so identified were eliminated from the modeling procedures. Where the canopy cover was estimated as a negative percentage, such values were adjusted to zero. Coefficient of determination (R^2), adjusted R^2 and root mean square error (RMSE) were computed for each model.

5.3.4. Validation

Models were validated using the leave-one-out cross validation. Predicted R^2 was calculated in Minitab to indicate how well the model predicts responses for new observations. It is calculated by systematically removing each observation, developing the regression using the remaining points and determining the model prediction for the removed point. This is continued for all the observations in the data and a predicted R^2 reported for the whole model. Larger the predicted R^2 value, better the model's predictive capability.

Squared semi-partial correlations were calculated to indicate the unique contribution of each variable to the regression model. It tells is how much the R^2 decreases if that variable is removed from the regression equation. It is computed by taking the difference in R^2 between a regression on all variables and a regression using all but that variable. Each variable is removed systematically and this difference between the R^2s is computed.

5.4. Results

For mines, a 9 variable model was chosen from the best subsets output using the selection criteria (Table 5.2). Some prominent spectral variables were focal means for leaf-off band 4, leaf-on and leaf-off NDVI, and leaf-on TC1. Terrain variables were represented by focal mean layers of cosine and sine aspect and slope (Table 5.3). For non-mines, a 10 variable model was identified from the best subsets regression using the selection criteria (Table 5.2). Four variables occurred within both the mined and non-mined models, and with the same sign: the spectral variables leaf-on and leaf-off NDVI mean; and the terrain variables sine and cosine aspect means. All four of these variables were also selected for the combined model. For mixed mine/non-mine photo-plots, a 5 variable model was chosen from the best subset regression output with fit parameters as reported in Table 5.2. Of the 4 variables in common among the other 3 models, only leaf-off NDVI also occurred within the mixed mines/non-mines model. A different set of variables were chosen, comprising of Leaf-on TC 3 mean, Leaf-off TC2 mean, Sine aspect mean etc. For combined, an 10 variable model was chosen from the best subsets regression (Table 5.2), with several of the selected variables also represented in both mines and/or non-mines (e.g. leaf-on and leaf-off NDVI mean layers, cosine and sine aspect mean layers) and some that were not present in any (Leaf-on B1 stdev, Leaf-on B5 mean).

Table 5.2. Best subsets results for the four models, indicating the model performance based on the selection criteria.

Groups	No. of variables	R^2	Adjusted R^2	Mallow's Cp	Standard error
Mines	9	71.2	69.4	5.8	0.19
Non-mines	10	66.1	65.5	7.2	0.16
Mixed	5	42.1	40	5.9	0.17
Combined	10	64.2	63.8	8.5	0.18

The zero-adjustment procedure (i.e. the manual setting of negative woody canopy density estimates to zero) improved the fit parameters for mined and combined models (Table 5.4). The mined regression model showed satisfactory fit (R^2 =0.78, Pred. R^2 = 0.71). For non-mines,the woody canopy estimating model yielded an R^2 of 0.69 and Pred. R^2 of 67.23. The mixed model, with an R^2 of 0.53, and Pred. R^2 of 48.8, produced the least satisfactory performance. For combined, model fits were reported as: R^2 =0.68, and Pred. R^2 of 66.23, less than the mined model and marginally less than the non-mined model. The combined model was also applied separately on the mines and non-mines and their fit parameters were: mined points: R^2= 0.74; nonmined points: R^2 = 0.64, (Table 5.4). Comparing the model fits, the mined model had the highest predictive capability followed by the non-mined model. Both the mined and non-mined models showed validity by their Pred. R^2 scores. Mined- and non-mined-specific models had better predictive capability than the combined model.

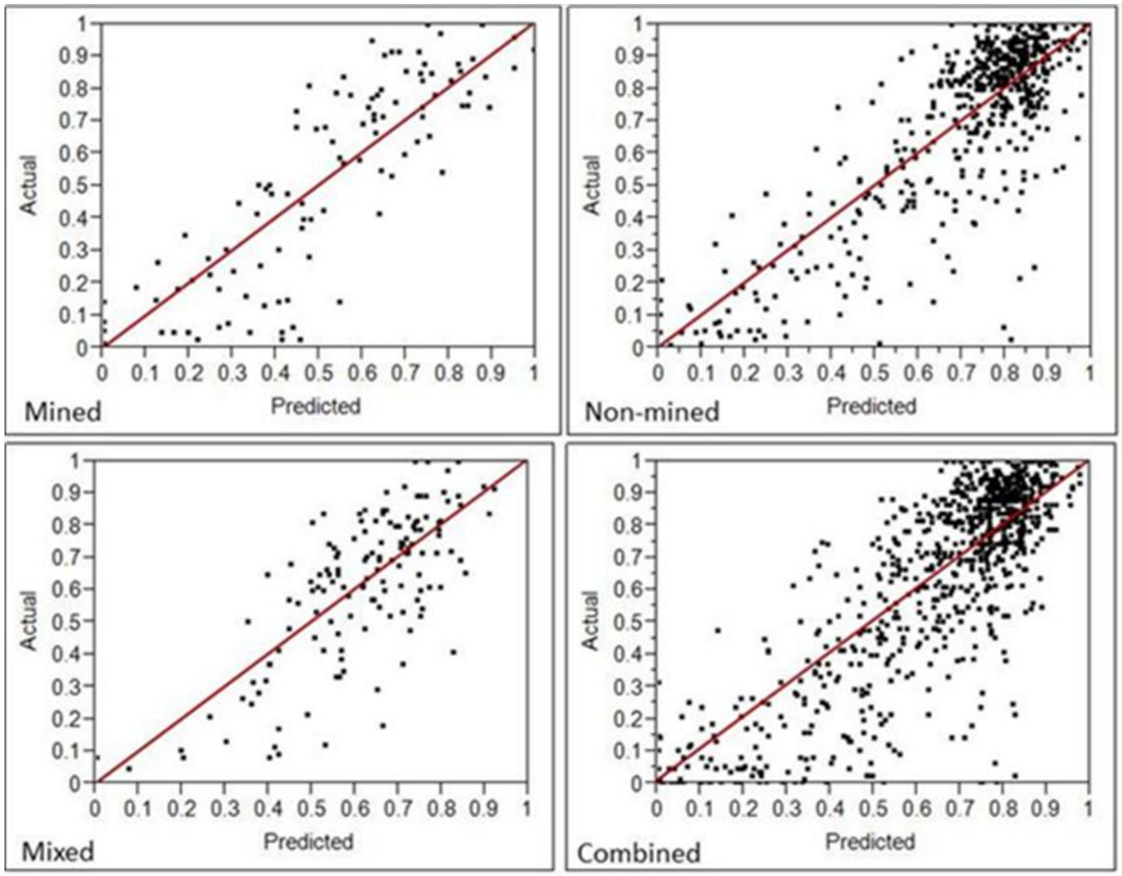


Figure 5.4. Predicted canopy versus actual woody canopy density for the four models after zero adjustment. Red line shows 1:1 relationship.

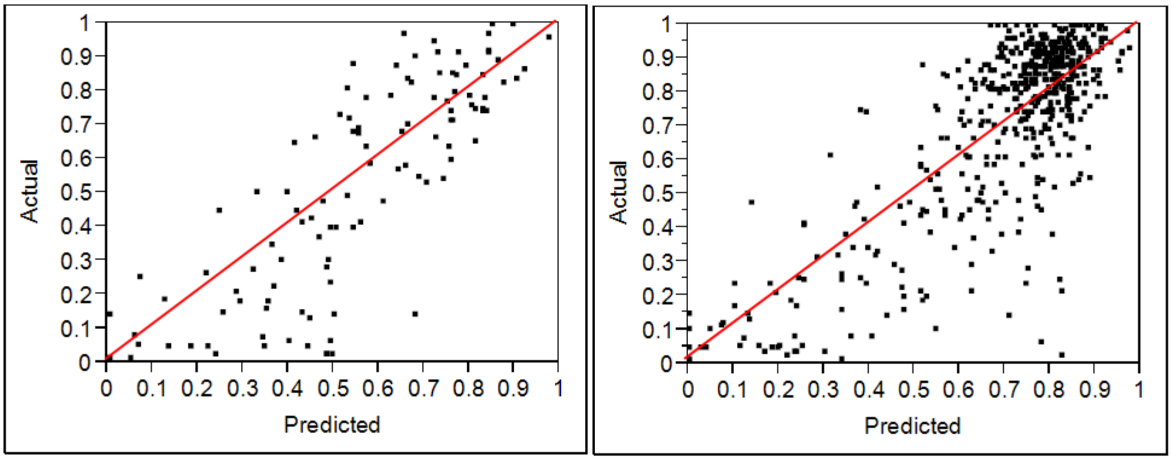


Figure 5.5. The combined model is fitted separately on mined (a) and non-mined points (b). Predicted woody canopy density is plotted on the X axis and Actual (Reference sample) woody canopy density on Y axis, for both the plots. Red line shows 1:1 correspondence.

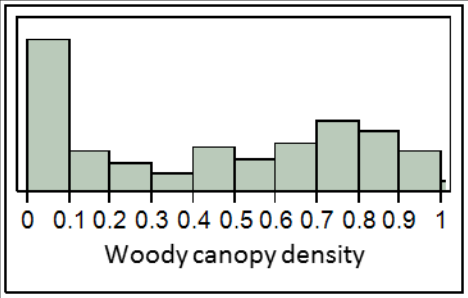
Table 5.3. Parameters and coefficients selected for the woody canopy cover estimation models; the dependent variable is woody canopy density, expressed as a percent. Explanatory variables are normalized to a 0 to 1 scale. If a coefficient is not listed for a any given model, that independent variable was not selected for use in that model.

Model parameters	Mines	Non-mines	Mixed	Combined
Intercept	-0.28	-0.43	0.45	-0.23
Independent Variables				
Leaf-on B1 stdev				1.48
Leaf-off B5 mean				-4.96
Leaf-on B4 stdev		-0.19		
Leaf-off B4 mean	-4.41			
Leaf-off B1 stdev	0.12			
Leaf-on TC1 mean	0.84			
Leaf-on TC2 mean		-2.87		0.45
Leaf-on TC3 mean		0.53	0.61	
Leaf-on TC3 stdev		-0.89		
Leaf-off TC2 mean		-0.48	-0.35	-0.15
Leaf-off TC3 mean		-0.01		-5.023
Leaf-on NDVI mean	0.79	1.62		1.26
Leaf-on NDVI stdev	-2.01			-1.83
Leaf-off NDVI mean	1.42	1.37	0.98	0.63
Aspect stdev			-0.73	
Cosine aspect mean	-0.14	-0.10		-0.16
Sine aspect mean	0.08	0.06	0.07	0.07
Slope mean	0.75			

Table 5.4. Fit parameters of the models (after zero adjustment where needed)

Groups	R^2	Adj. R^2	RMSE	Pred.R^2	Outliers
Mines	0.78	0.77	0.16	71.24	5
Non-mines	0.69	0.69	0.15	67.23	4
Mixed	0.53	0.51	0.16	48.48	4
Combined, applied to:					
• **1. All data**	0.68	0.68	0.16	66.23	13
• **2. Mines only**	0.74	0.74	0.17		
• **3. Non-mines only**	0.64	0.64	0.16		

Mine



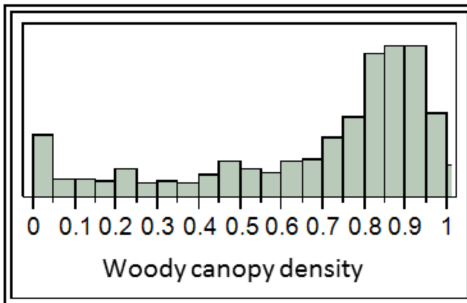
Quantiles

100.0%	maximum	1
99.5%		1
97.5%		0.97143
90.0%		0.88857
75.0%	quartile	0.75952
50.0%	median	0.4619
25.0%	quartile	0.05
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

Moments

Mean	0.4423669
Std Dev	0.3453774
Std Err Mean	0.0296159
Upper 95% Mean	0.500938
Lower 95% Mean	0.3837958
N	136

Non-mine



Quantiles

100.0%	maximum	1
99.5%		1
97.5%		1
90.0%		0.95238
75.0%	quartile	0.90476
50.0%	median	0.80952
25.0%	quartile	0.55714
10.0%		0.17143
2.5%		0
0.5%		0
0.0%	minimum	0

Moments

Mean	0.6958833
Std Dev	0.2855428
Std Err Mean	0.0120556
Upper 95% Mean	0.7195631
Lower 95% Mean	0.6722036
N	561

Figure 5.6. Woody canopy density (expressed as decimal fraction) histograms for mined and non-mined reference samples, as developed by photo-interpretation.

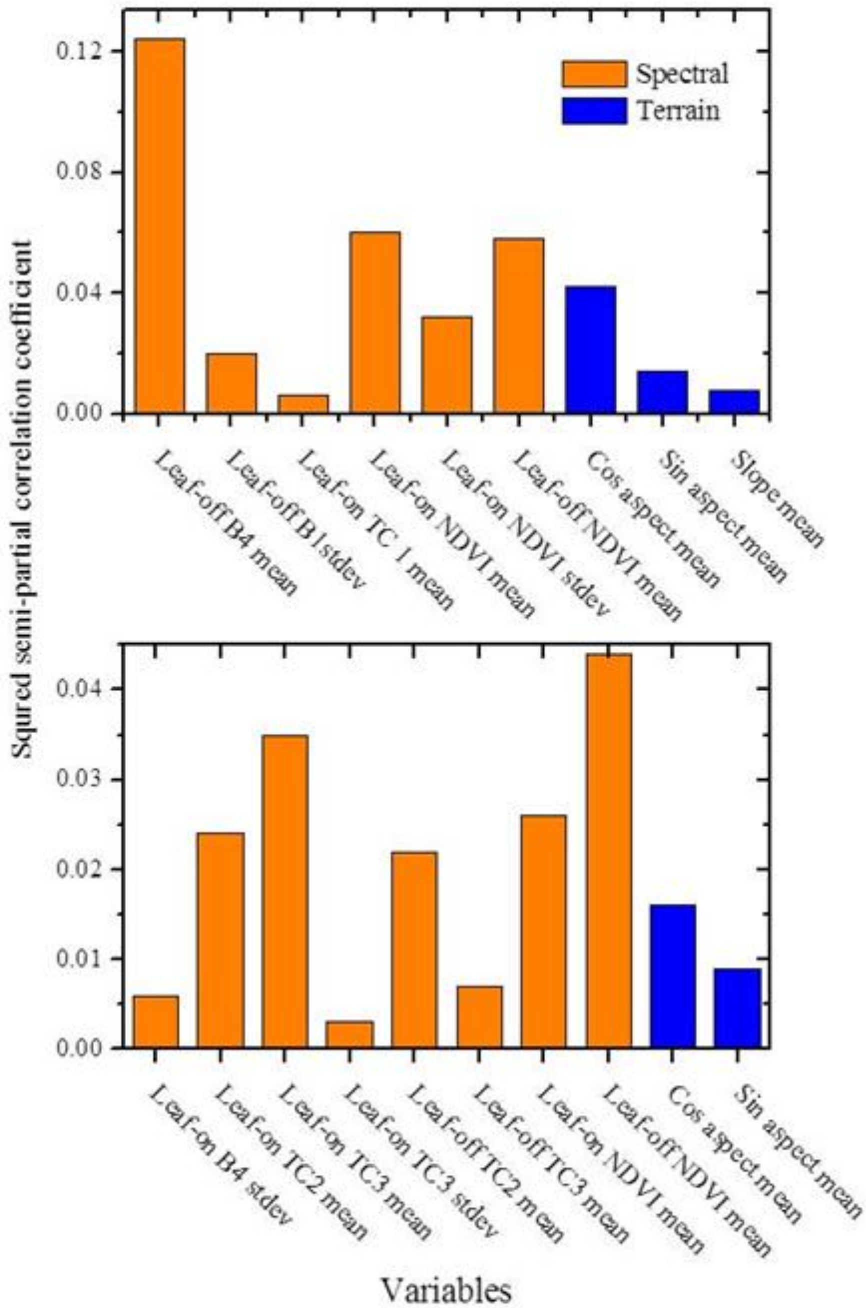


Figure 5.7. Squared semi-partial correlation coefficients using type III SS shows the unique contribution of variables in the mined and non-mined models.

Raster calculator in ArcMAP™ was used to display the results from the mine model. Figure 5.8 displays the results.

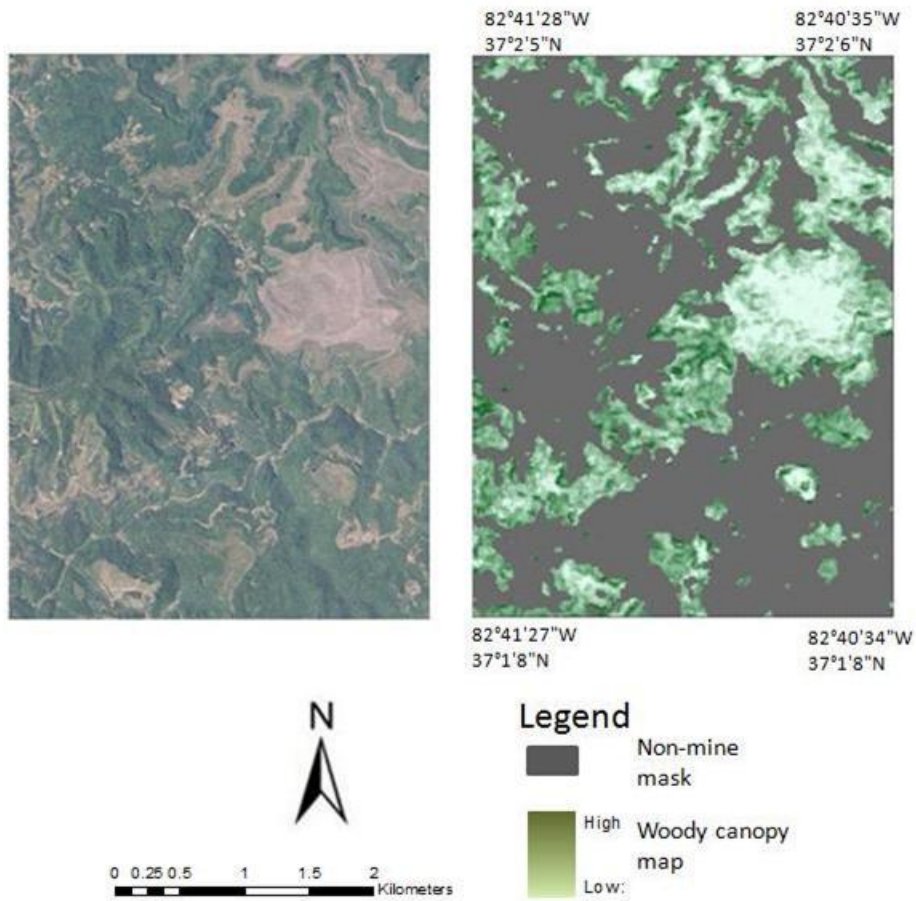


Figure 5.8. Woody canopy density displayed on the right and a NAIP 2008 aerial photo from the same area on the left. Since the woody canopy density map is obtained from the mined model, a non-mine mask is applied on the map to occlude the non-mined areas. Mask is developed using the non-mined classes identified in Sen et al. (2011) mine land identification study.

5.5. Discussion

The results from comparing the canopy cover estimates from NLCD 2001 and the photo-interpreted reference samples showed that the NLCD 2001 product provided inaccurate estimates of tree canopy cover for mined areas. This difference could by partly attributed to the fact that the NLCD data were compiled using pre-2001 Landsat images, while the NAIP photos were from 2003, a time gap in which there can be some degree of increase in vegetation. Huang et al (2001) state that such results could be caused by the highly variable nature of mixing between spectral characteristics of canopy and non-canopy surface materials, a situation commonly found in mined areas. They also point to the topographic and atmospheric noise in Landsat data as possible sources of error. Since mined areas have widely variable topography; this could be a reason for inaccuracy of the NLCD over mined areas. The USGS cautions against the use of the data in local levels such as county scale applications (USGS 2007). Greenfield et al. (2009) conducted a study to test the validity of the NLCD 2001 percent tree canopy dataset using a photo-interpreted test sample, and found that NLCD significantly underestimated the canopy cover, particularly at the county level. The mean difference between photo interpreted and 2001 NLCD estimates for tree cover is 11.3 %. The authors suggested that the causes of the inaccuracy of the NLCD product could be from the following: failure to incorporate the heterogeneity of landcover within the mapping zones that were assumed homogeneous and errors in collection of training data and data preparation by the mapping teams. Nowak and Greenfield (2010) conducted a comprehensive error analysis for the conterminous United States, comparing the NLCD 2001 estimates to photo-interpreted random samples from each map zone. They also categorized the samples by their landcover classes (forest, developed, agricultural/grassland and other/barren areas). Their results revealed that the NLCD 2001 and photo-interpreted estimates differ significantly (95% confidence) for map zones 53 and 57, which cover our study area. The numbers are particularly large for the “other/barren” cover class, 18.5 and 34.8 for zones 53 and 57 respectively.

This study showed that a method similar to the NLCD 2011 pilot study protocol can be used for mined areas; the mined model has reasonably high R^2 and adjusted R^2, higher than all the other models, and also performed well in a cross validation test. The intent of the study was to examine if the mined and non-mined areas can be modeled for woody canopy density together or separately. The results indicate both the mined and non-mined models outperform the combined model, suggesting that the mined and non-mined lands need to be estimated separately and that a combined model does not represent woody canopy cover for the area in general. Woody canopy density of mined and non-mined land is very different (Figure 5.6). Non-mines are mostly undisturbed forests with dense canopy cover, which have often attained canopy closure. Woody vegetation on reclaimed mine areas is often sparse (Figure 5.9).

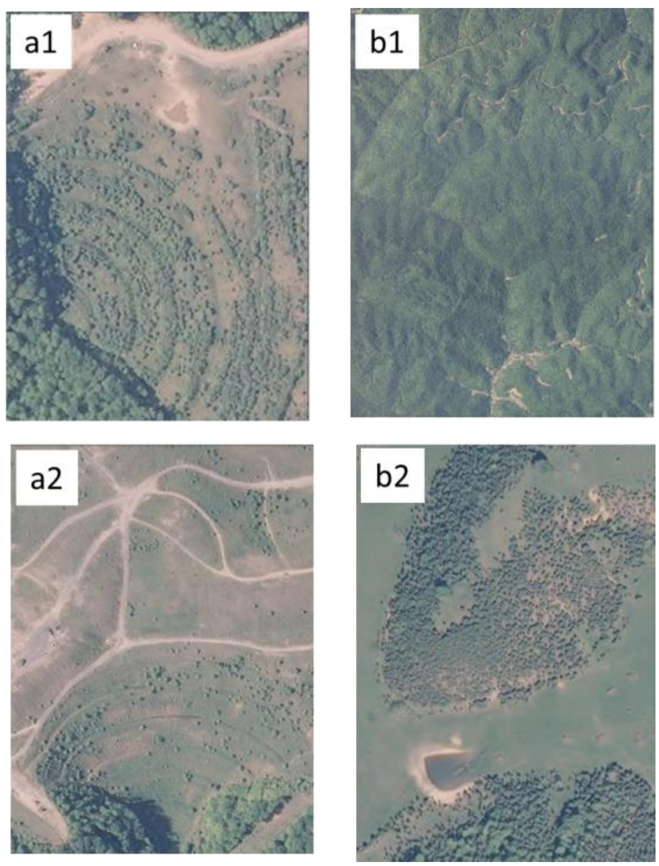


Figure 5.9. Differences in woody canopy cover in mined and non-mined lands. a1: woody vegetation in a typical reclaimed mine; b1: a typical non-mined landscape with dense canopy cover; a2: a sparsely vegetated reclaimed mine; b2: A non-mine area with little woody canopy being used for pasture.

Another reason why the mines model has outperformed the non-mines model may be the characteristics of the areas lacking woody canopy. On the mines, these areas are commonly covered with herbaceous vegetation, whereas the non-woody canopy areas of the non-mined lands are more heterogeneous. There are also inherent differences in site and soil conditions between the reclaimed mines and non-mined areas, which affect the vegetation recovery and therefore the canopy cover in the terminal year. These factors contribute to differences in canopy densities and are reflected in the choice of variables and the variable estimates. The combined model has lower fit parameters than the mined and non-mined models; also, when applied separately on the groups, the results were inferior to the mined-/non-mined –specific model. This suggests that the set of variables chosen for the combined model fails to estimate the canopy cover in the area as a whole, again pointing to the fact that the mined and non-mined areas need separate models.

Examination of the squared semi-partial correlation coefficient for the variables in the mined model (Figure 5.7) shows that leaf-off band 4 mean has the highest contribution to the prediction. Band 4 or the near-infrared band has been used to differentiate between vegetation varieties by making the best spectral separation between deciduous and coniferous vegetation (Nemani and Running 1997). Conifer canopies have lower canopy reflectance than the deciduous broad-leaf canopies, and have been reported to have low NIR values than broadleaves (Hall et al. 1992). Coniferous trees such as eastern white pine have been widely planted in the reclaimed mines of southwestern Virginia because of its adaptability to acidic soils and its fast growth that enables meeting of the five-year bond release requirement (Holl et al. 2009). Leaf-on and leaf-off NDVI are two other prominent contributors to the mined model. NDVI in general has been popularly reported to suitably reflect vegetation condition (Lefsky et al. 2001; Prakash and Gupta 1998; Schroeder et al. 2007; Wickham et al. 2007). Leaf-on NDVI represents green vegetation in general while leaf-off NDVI represents the sparse canopy cover in the winter months, a condition that is typical for mines in general. This variable possibly also represents the coniferous vegetation in the winter months, when all other trees have lost their leaves.

Two of the chosen topographic variables: cosine and sine aspect represent the northness and eastness respectively. It is generally well known that woody vegetation characteristics are affected by aspect. These two terrain variables therefore feature as important contributors for both mines and non-mines. Slope, another terrain variable has also been found to be positively correlated with woody canopy for mines. Relatively flat reclaimed mines often have higher levels of soil compaction and poor internal drainage, hindering vegetation growth.

For non-mines leaf-on and leaf-off NDVI and leaf-on TC band 3 (wetness band) have high contributions. Previous studies have shown that the wetness band is well correlated to shadowing effects (Song et al. 2007). It is presumed that high levels of canopy shadowing in the undisturbed forests, caused by tree size heterogeneity, has resulted in the relative importance of this layer. TC band 2, i.e. the greenness band is also seen to be important, though it is found to have negative estimates. The Song study showed that greenness increases rapidly with increasing vegetation maximizing around 30 years and then starting to decrease as the stand gets older. Since most of the non-mined forests are in their old-growth/mature stage, this could be a possible reason for the negative sign.

One drawback of this study is that the mined population does not have equal representation in the low and high canopy density bins (Figure 5.6). The mined training data is limited by the sampling strategy which mostly captured low to bare mined areas but failed to capture similar number in the high vegetation category. The non-mined portions in the study area have low representation in the low canopy levels, the only representation being in the southern portions of the Russell County which are located outside of the mining areas. This is however a limitation of the study area and not of the sampling strategy. Two variables that proved to be very important in the NLCD 2011 pilot study areas were eliminated from our study were the NLCD 2001 tree canopy estimates and the landcover type. NLCD 2001 canopy cover estimates for mines was tested and found to be inaccurate; the location of mines was not very accurately portrayed in the NLCD 2001 landcover map and hence it was eliminated as well. This study considers canopy cover to include all woody species. No distinction is made between the ecologically beneficial native tree species and the invasive species that negatively impact the forest succession process. The drawback is in part due to inability to distinguish them in the resolution of the NAIP photos.

The mixed category was found to have unsatisfactory R^2 values. We hypothesize that the inherent heterogeneity of this category contributes to such modeling results. The mine-non-mine proportion can vary significantly within the mixed data points; also, the non-mined landcover can be forests or unvegetated surfaces.

5.6. Conclusion

Based on the results of this study, we conclude the following:

- Woody canopy cover can be robustly estimated in the central Appalachians using Landsat imagery and digital terrain data.
- Woody canopy cover on reclaimed mines is best modeled separately when ensemble methods are not used.
- The NLCD 2011 canopy cover sampling strategy is robust and the technique is objective, fast, and accurate.
- The ability to remotely estimate woody canopy cover on reclaimed mines will help scientists and managers evaluate and improve reclamation practices.

5.7. Acknowledgements

Sincere thanks to Dr. John W. Coulston (Forest Inventory and Analysis Program, USDA Forest Service, Southern Research Station) for his help with developing the 4x and 9x FIA samples and his suggestions on the modeling activity, and to Doug Mullins and Daniel Kestner, Virginia Department of Mines, Minerals and Energy, for providing terrain data that were essential to this research.

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Chapter 6 Utility of Landsat-Derived Disturbance/Recovery Parameters for Estimating Woody Canopy on Appalachian Surface Coal Mines

6.1. Abstract

Woody canopy cover is an important indicator of ecosystem recovery on reclaimed surface coal mines. Using an interannual chronosequence of Landsat normalized difference vegetation index (NDVI) images, we computed four parameters describing the initial mining disturbance and subsequent post-reclamation recovery. These parameters are the time since mining (equivalent to recovery time), the minimum NDVI value, the maximum NDVI value in seven years of recovery, and the seven-year recovery slope. Our objective was to determine whether these parameters, alone or in combination with variables being used in the 2011 NCLD canopy cover mapping effort, enable robust estimation of woody canopy cover on reclaimed surface coal mines in the USA's central Appalachian coalfields. Reference woody canopy data were developed by photo-interpretation of 139 random samples on 2008 leaf-on National Agriculture Imagery Program (NAIP) ortho-images. Of the disturbance/recovery parameters, only the recovery time is related to woody canopy cover (R^2 0.45, Adj. R^2 0.43, RMSE 14%). Adding leaf-on and leaf-off NDVI images acquired in the same growing season as explanatory variables improved the model (R^2 0.54, Adj. R^2 0.53, RMSE 13%). The time that has elapsed since the original forest-replacing disturbance, as determined through analysis of interannual multitemporal Landsat data, is thus strongly related to woody canopy cover on reclaimed surface coal mines – and perhaps for other disturbances as well.

6.2. Introduction

The eastern USA's Appalachian region supports the world's most extensive temperate deciduous forests (Riitters et al. 2000). Appalachia's forests support produce high-quality timber, diverse wildlife habitat, protect watersheds and provide other ecosystem services that are essential to human activities in the region's mountainous landscape, and produce high-quality timber. However, coal surface mining has caused extensive forest disturbance (Drummond and Loveland 2010; Sayler 2008). More than 600,000 hectares in Appalachia have been mined for coal since 1980 under the USA's national coal mine reclamation law, the Surface Mining Control and Reclamation Act (SMCRA)(Zipper et al. 2011).

In a world characterized by increasing natural resource demands, the mined areas of Appalachia constitute a significant land resource. These lands, however, are often unmanaged and unutilized. Although studies of these lands have been performed at the site level (Simmons et al. 2008), little is known about these lands' nature and properties collectively. Given the potential for active interventions such as native forest restoration and conversion to use for production of woody biomass (Brinks et al. 2011; Skousen et al. 2009), both the current vegetation status and the nature forest ecosystem regeneration processes are of interest on these lands.Herbaceous vegetation establishes readily on Appalachian coal mines reclaimed under SMCRA (Angel et al. 2005), and vegetative cover on these lands generally develops rapidly (Sen et al. 2011). Although generally sparse or non-existent at the onset of reclamation, woody canopy can be expected to develop over time for properly reclaimed mines. Such woody canopy may include native foretst trees and shrubs, depending on the reclamation practices employed.

Sen et al. (2011) used an interannual chronosequence of Landsat vegetation indices (VIs) images to identify surface coal mines. Three vegetation indices were tested; the normalized difference vegetation index (NDVI) was found to be the best for pixel-based analysis. Three parameters describing the initial mining disturbance and subsequent recovery post-reclamation were developed, as follows: the minimum NDVI value, the maximum NDVI value in seven years of recovery, and the seven-year recovery slope. Once the analysis was complete the number of years since mining was also computed. Our objective was to determine whether these four variables, alone or in combination with variables being used in the 2011 NCLD canopy cover mapping effort, enable robust estimation of woody canopy cover on reclaimed surface coal mines in the central Appalachian coalfields.

6.3. Method

6.3.1. Study area

The study area encompasses the coal mining areas in the four counties of southwestern Virginia (Figure 6.1). These areas have been heavily surface mined throughout the SMCRA-regulated mining period. The area's primary landcover is forest, but numerous non-mining forest disturbances also occur, including industrial, commercial, residential and transportation infrastructure development. The study area contains little agriculture, and most of that which does occur in livestock grazing on reclaimed mines.

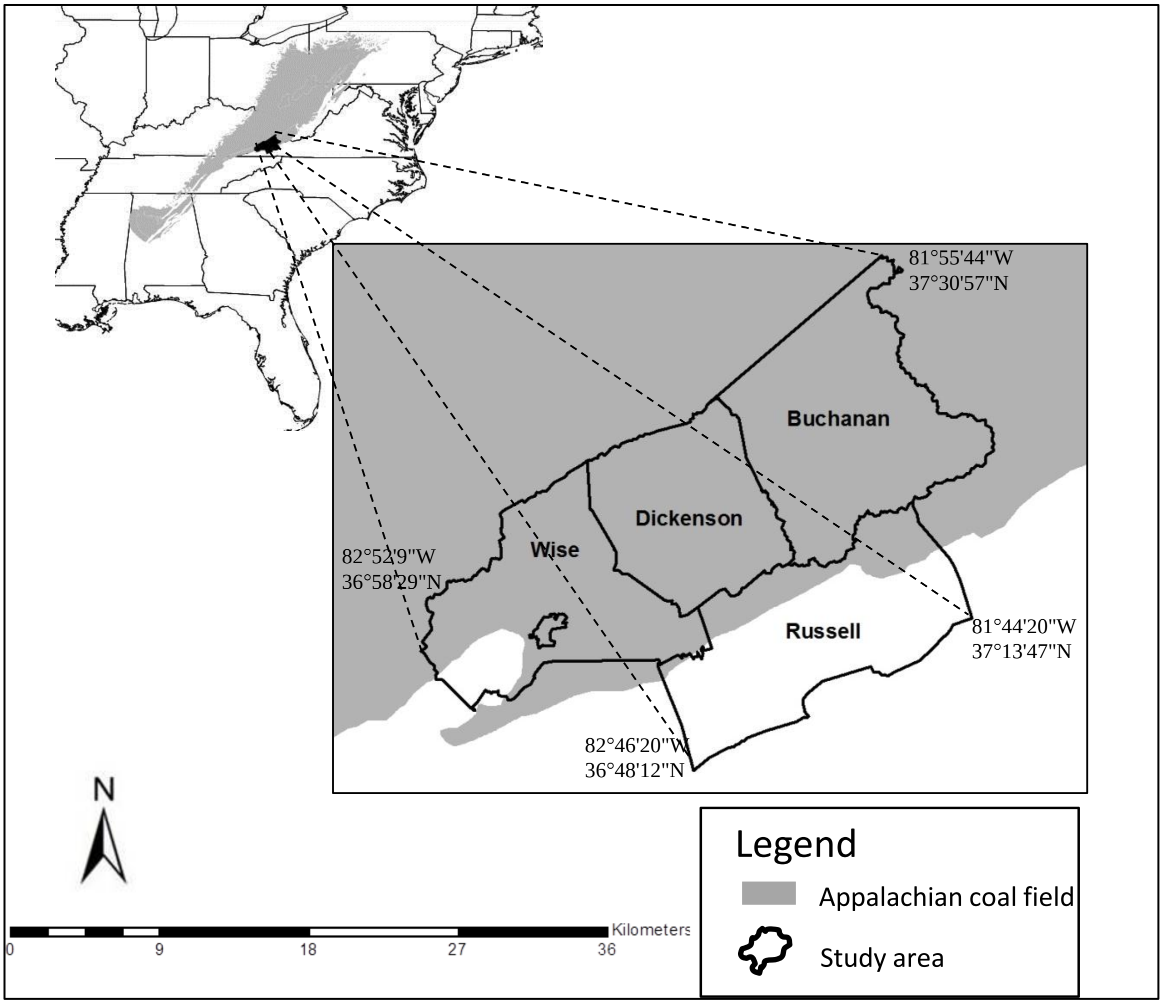

Figure 6.1. The study area encompasses the section of the Appalachian coalfield that occurs in four southwestern Virginia counties: Wise, Dickenson, Buchanan, and Russell.

6.3.2. Image chronosequence

The dataset used for analysis consisted of 23 Landsat images (Table 6.1; Sen et al. 2011), all from WRS-2 path 18 row 34. Best available leaf-on images for each year were chosen. Two years (1992 and 1996) are missing because suitable cloud-free leaf-on images were not available. All images were acquired as level 1T product in a standard terrain-corrected form. Co-registration was verified and radiometric and atmospheric corrections were done using the Landsat Ecosystem Disturbance Adaptive System (LEDAPS) routine (Masek et al. 2006). The LEDAPS surface reflectance product was used. Clouds and cloud shadows were visually identified and eliminated from the individual images by manual digitization.

Table 6.1. Landsat image dates and their assigned number in the chronosequence. Images from 1992 and 1996 were unavailable due to cloud contamination in the growing season.

Image Date	Chronosequence Number	Image date	Chronosequence Number
9/17/1984	1	5/19/1998	13
9/20/1985	2	9/3/1999	14
6/19/1986	3	6/9/2000	15
6/6/1987	4	8/15/2001	16
6/8/1988	5	5/22/2002	17
6/11/1989	6	6/2/2003	18
6/30/1990	7	9/24/2004	19
9/21/1991	8	9/11/2005	20
6/6/1993	9	7/12/2006	21
8/28/1994	10	9/17/2007	22
8/31/1995	11	9/3/2008	23
9/5/1997	12		

Note: all images from Landsat Thematic Mapper (TM) except 5/22/2002, from the Enhanced Thematic Mapper Plus (ETM +) sensor.

6.3.3. Disturbance/Recovery Parameters:

Sen et al. (2011) developed four disturbance/recovery parameters (Figure 6.2), additional description and abbreviation is as follows:

- Disturbance minimum (*Dmin*): This is the minimum VI value reached in the multitemporal trajectory. This value is often lower for mines than for other disturbances.

- Recovery slope (*Rslope*): Mines that have been reclaimed under SMCRA experience vegetation restoration efforts that lead to rapid vegetative development. The slope is calculated as the least square estimate over seven recovery years. Mining typically has steeper recovery slopes than urban developments.
- Recovery maximum (*Rmax*): This is the maximum VI value reached at the end of a seven years recovery time period. Also because of focused vegetation restoration effects mandated by SMCRA, mines often show higher *Rmax* values within the 7-year seven-year diagnostic period than other disturbances.
- *Recovery Period* is the number of years since the year of *Dmin* for identified mines.

Figure 6.2 shows NDVI chronosequences for an unmined and mined area, and designates the disturbance/recovery parameters for the mined area. Figure 6.3 shows the results from the classification for a small portion of the study area: a map identifying the reclaimed mines and a map of the year of mining for the identified mines.

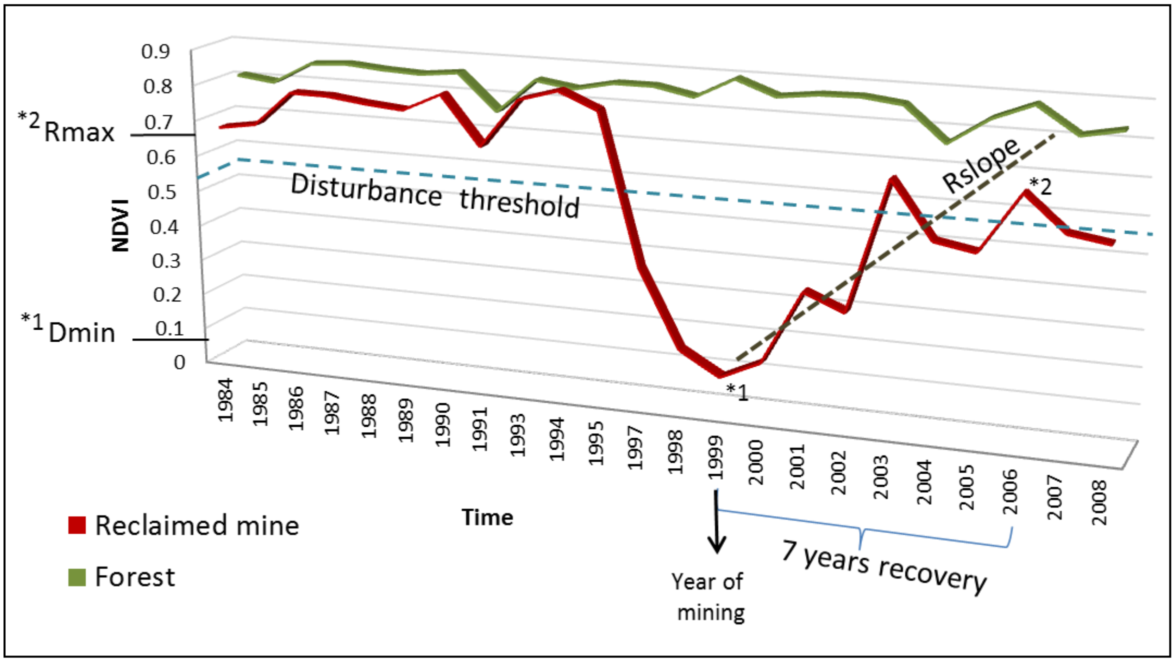

Figure 6.2. Figure showing a typical mining trajectory computed from NDVI, obtained from a reclaimed mine pixel and an unmined forest. Also shown are three disturbance/recovery parameters: Disturbance minimum (Dmin), recovery maximum (Rmax), recovery slope (Rslope); a fourth parameter, Recovery time, can be derived from the year of mining. Rmax and Rslope are computed for seven-year recovery periods. The disturbance threshold, NDVI = 0.58, was derived empirically (Sen et al. 2011). All pixels with NDVI values that fall below this threshold on any image within the chronosequence are defined as “disturbed”.

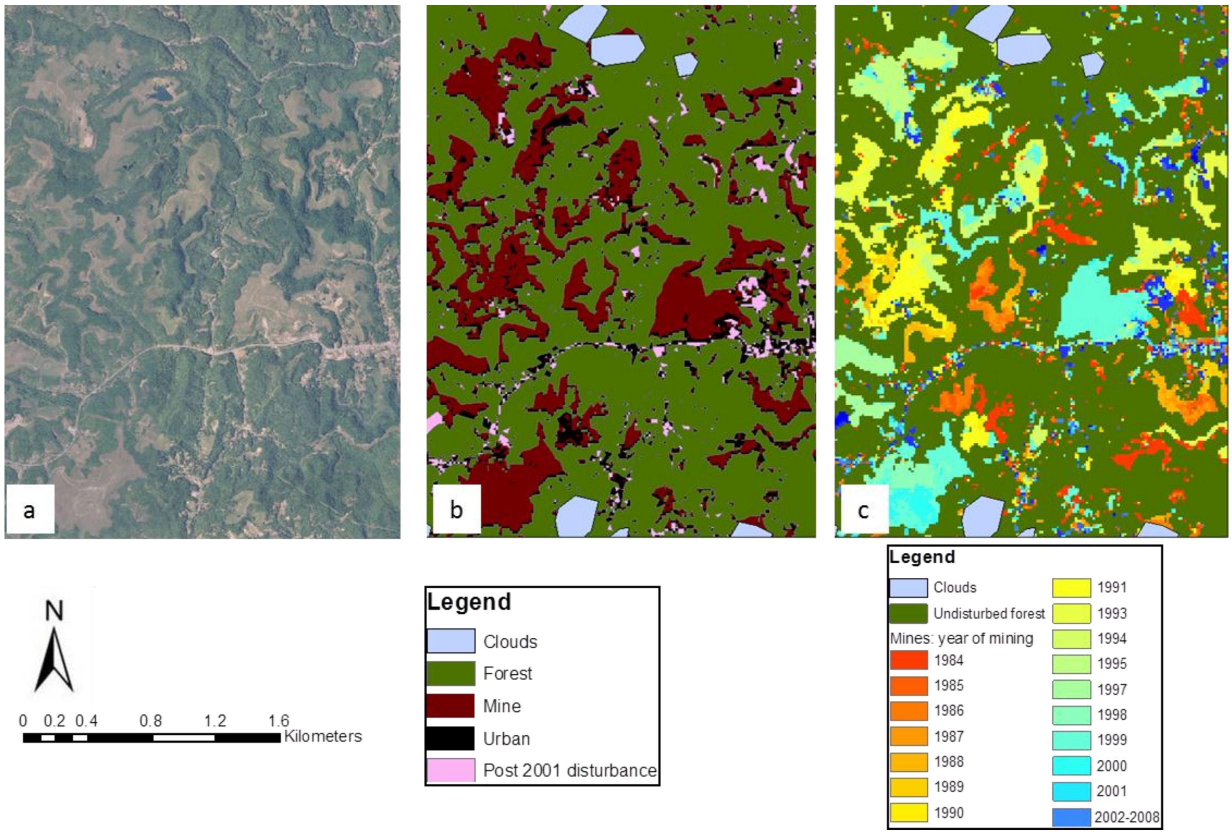

Figure 6.3. Three representations of a study area segment, based on Sen et al. (2011) results a: NAIP image from 2008 for reference, b: pixel-based classifications of the same area; c: Disturbance years, showing year of mining (1984-2001) and year of disturbance (2002-2008) for post-2001 disturbance areas.

6.3.4. Woody canopy estimation using disturbance/recovery parameters

Woody canopy density was estimated by photo-interpretation for a random sample of mined Landsat pixels. Photo-interpretation was performed using leaf-on aerial photos from 2008 obtained from the National Agricultural Imagery Program (NAIP) (USDA 2010). Using the Sen et al. (2011) results, sampling points were defined within mined areas, stratified by year of mining. Within this sampling framework, 139 sampling points were selected based on the following criteria:

- No re-mining after the year of mining documented by Sen et al. (2011): This was checked using two methods: a visual check of historical aerial photos (NAIP 2003, 2005 and DOQQ from mid 90s); and using the NDVI temporal profile to determine if NDVI values dropped below the disturbance threshold value after the recovery period.

- Relatively homogeneous land cover in surrounding pixels: This was determined via visual inspection.

A vector grid of 30mx30m was created to mimic Landsat pixels in ArcMap (ESRI, Redlands, CA). For each grid cell containing a sampling point, the woody canopy was manually digitized to form polygons using the NAIP leaf-on photo from 2008 (Figure 6.4). The woody-canopy polygon areas were summed for each sampling-point grid cell and the woody canopy density was computed by dividing it by $900m^2$.

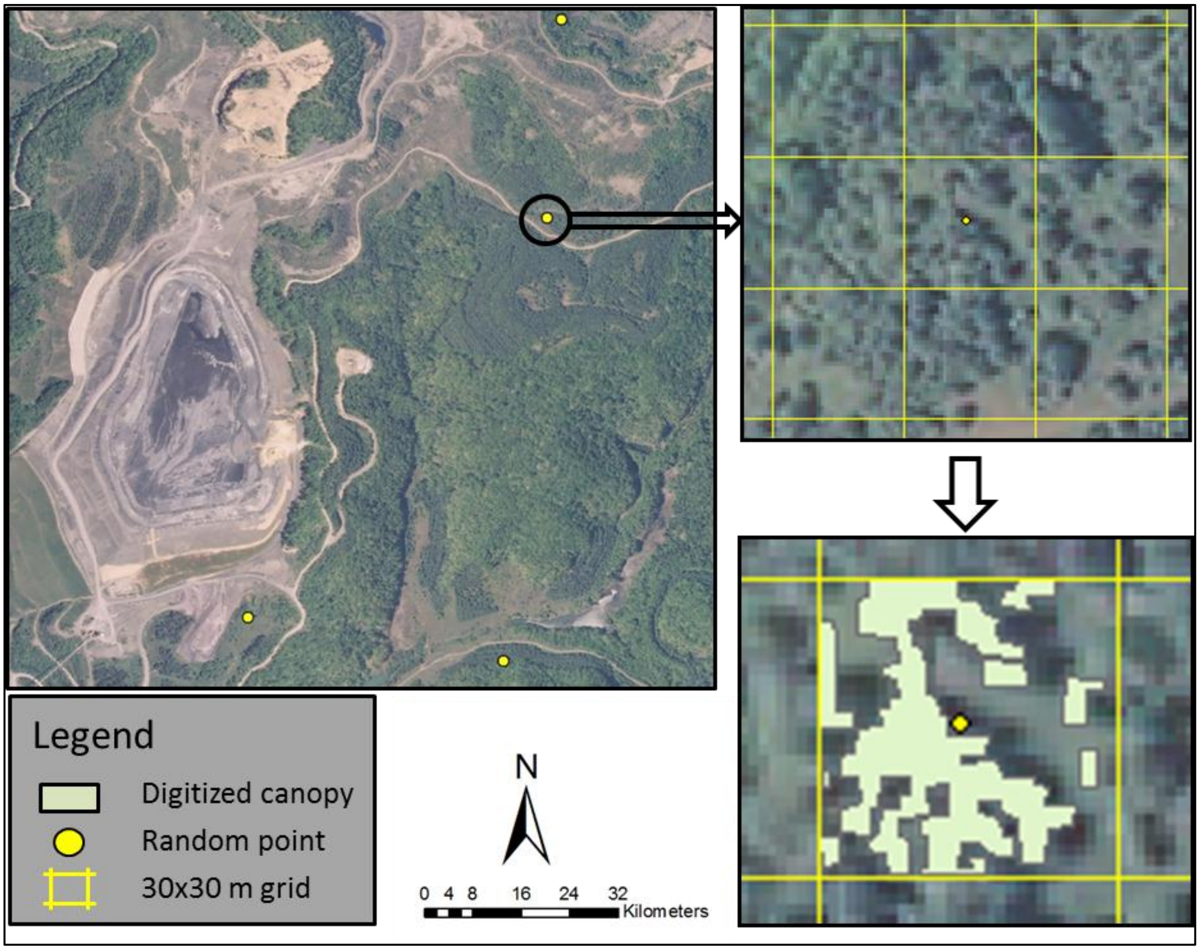

Figure 6.4. A representation of the sampling method. Left: Sample points are located within mined areas, stratified by year of mining, on a 2008 NAIP image. Upper right: The sampling point is located within a 30mx30m grid cell, and a nine-cell area centered on that grid cell is visually inspected for land cover homogeneity. Lower right: Woody canopy within the sampled grid cell is manually digitized, using visual procedures to estimate separation of actual woody canopy from canopy shadows.

Disturbance/recovery parameter extraction:

The Landsat images were transformed to NDVI in ERDAS Imagine (v. 9.3, Leica Geosystems Inc.) and stacked to form a NDVI image stack. The pixel-based classification algorithm (Sen et al. 2011) was run on this image stack (disturbance threshold used: 0.58, number of recovery years used: 7), and a disturbance image was produced containing four bands representing the four disturbance/recover parameters. Parameter values were extracted from this image for each of the photo-interpreted grid-cell samples.

Model specification

Models to estimate woody canopy as a function of the four disturbance/recovery parameters were evaluated using best subset regression in Minitab statistical software (v. 16, Minitab Inc., State College PA, USA). In the regression output, two criteria were used for model selection: high adjusted R^2 values and Mallow's Cp ≤ (Number of variables +1).

6.3.5. Woody canopy cover estimation with additional spectral and terrain variables

Sen (2011) modeled woody canopy cover for both mined and non-mined lands in the study area as a function of spectral and terrain variables derived from geospatial datasets. Sen (2011) developed the response variable by photo-interpretation of NAIP 2008 photos for samples obtained from a spatially randomized FIA sampling grid. At each sampling point, potential modeling variables were estimated for 9 Landsat pixels (a 3x3 matrix). A mean value and standard deviation were calculated for each modeling variable using pixel values at each sampling point. Fifty-four potential explanatory variables were specified in this manner, and then tested for multicollinearity; for each highly correlated variable pair (spearman's rho > 0.8), the variable less correlated with the woody canopy cover response was eliminated; this exercise produced 29 potential explanatory variables, which were evaluated as potential estimators of woody canopy cover using best subset regression, followed by a standard least square multiple regression to specify a model from among the best-subset selected variables. This procedure was used to estimate 4 separate woody canopy cover estimation models: one each for mines, non-mined areas, "mixed" sampling points which included mines and non-mines, and "combined," a model developed from all sampling points. Eighteen separate spectral and terrain variables were selected by Sen (2011) for use in one or more woody canopy cover estimation models, 12 as means and 6 as standard deviations. In this study, since a single-pixel based approach was used for response variable estimation, only variables defined by Sen (2011) as means were used.

Using the terminal image in the leaf-on chronosequence (9/3/2008), a corresponding leaf-off Landsat image (1/25/2009), and terrain data derived from a digital elevation model produced by Virginia Department of Mines, Minerals and Energy using Virginia Base Mapping Program (VBMP) 2007 data (VITA 2010), pixel values were extracted for these spectral and terrain parameters at the 139 sampling points.

Correlations of the variables with one another and with the response variable were examined to ensure lack of multicollinearity, as in Sen (2011). All variables (disturbance/recovery parameters, and the Sen (2011) spectral and terrain) were put through a best subsets regression in Minitab. Model selection criteria were: high incremental increase in adjusted R^2 and high incremental decrease in Mallow’s Cp. Model validity was judged by the predicted R^2 and the PRESS values.

6.3.6. Model evaluation

Predicted R^2 were calculated for both estimation models, as a means of indicating how well the models predict responses for new observations. It is calculated by systematically removing one observation, developing the regression model with the remaining, and then applying the model on the removed observation. This is continued for all the observations in the data and a predicted R^2 reported for the whole model. Larger values suggest models of greater predictability. PRESS is another statistic by which the model is validated. It is also another leave-one-out cross validation statistic; the lower the value, the better the validity. Squared semi-partial correlations were calculated to indicate the unique contribution of each variable to the regression model. It tells is how much the R^2 decreases if that variable is removed from the regression equation. It is computed by taking the difference in R^2 between a regression on all variables and a regression using all but that variable. Each variable is removed systematically and this difference between the R^2s is computed.

6.4. Results

6.4.1. Woody canopy estimation using disturbance/recovery parameters

The best subset results yield a model with recovery time as the sole predictor, an R^2 of 0.452, and an adjusted R^2 0.436 which also met the Mallow's Cp (0.8) criterion. That model is specified as:

Woody Canopy Density = 0.081 + 0.03*Recovery Time   Equation 6-1

where, woody canopy density expressed as a decimal fraction and recovery time as years. The other parameters did not contribute to this model, and models using other disturbance/recovery parameters were not significant at $p < 0.05$.

A plot of the recovery time vs. canopy density (Figure 6.5a) shows that despite some variability within each recovery year, there is a strong positive relationship of woody canopy density with recovery time. A model made by using recovery time as the sole predictor results in a R^2 of 0.452, adjusted R^2 of 0.436, RMSE 0.143 and a Predicted R^2 of 0.408. The predicted canopy density values when plotted against the actual values show positive relationship (Figure 6.5b).

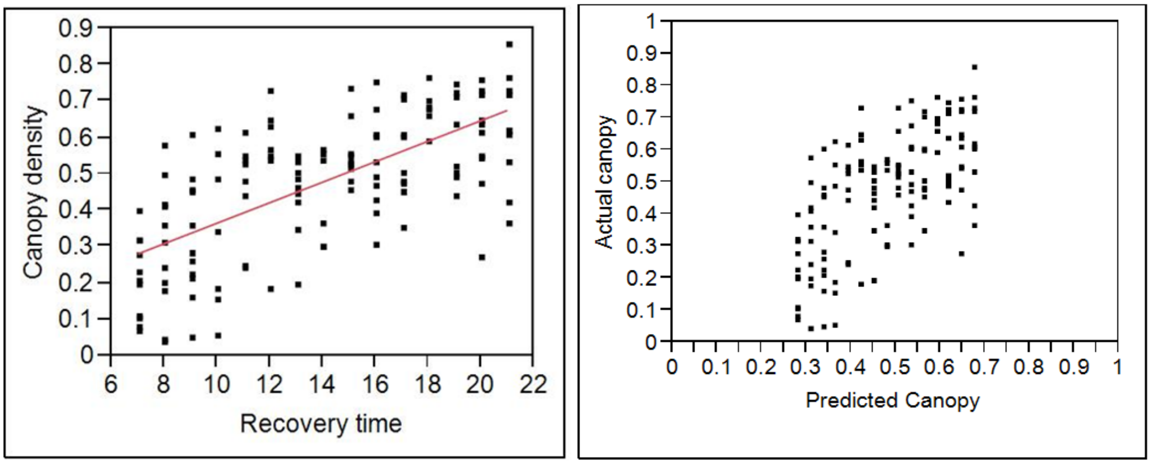

Figure 6.5. (a) Recovery time (years) plotted against woody canopy density, red line shows model fit. (b) Modeling result, using recovery time as the sole predictor, plotted against actual canopy density.

Table 6.2. Summary of fit for regression using Recovery time as the sole predictor in canopy estimation model

Summary of fit	
R^2	0.452
Adj. R^2	0.436
RMSE	0.143
Pred. R^2	0.408
PRESS	2.951

6.4.2. Woody canopy estimation with additional spectral and terrain variables

Correlation coefficients were calculated amongst the variable and the results are shown in Table 6.3. The table shows that Recovery time, leaf-on NDVI and leaf-off NDVI are well correlated with the response variable: woody canopy density. Two other variables, leaf-on TC band 3 and leaf-off TC band 2 are also found to be well correlated with woody canopy density, though they are also well correlated with leaf-on NDVI and leaf-off NDVI respectively.

Table 6.3 Potential explanatory variables; spearman coefficients (ρ) and p-values for correlations with the woody canopy density; and, for additional spectral and terrain variables derived from Sen (2011), the woody canopy cover prediction models within which they serve as explanatory variables

Predictors	ρ	p value	Sen (2011) Model			
			Mined	Non-mined	Mixed	Combined
Disturbance/Recovery Parameters						
Recovery time	0.64	<.0001*				
R_slope	0.06	0.4775				
D_min	-0.09	0.2547				
R_max	-0.03	0.7014				
Additional Spectral and Terrain Variables						
Leaf off_NDVI	0.34	<.0001*	x	x		x
Leaf on_NDVI	0.48	<.0001*	x			x
Leaf on_TC band 1	-0.15	0.0644	x			
Leaf on_TC band 2	0.19	0.0228*		x		
Leaf on_TC band 3	0.38	<.0001*	x		x	
Leaf off_Band 5	-0.15	0.0717				x
Leaf off_Band 4	0.06	0.4946	x			
Leaf off_TC band 2	0.24	0.0046*	x		x	x
Leaf off_TC band 3	0.19	0.0264*		x		x
sin_aspect	0.05	0.5220	x	x	x	x
cos_aspect	-0.06	0.4344	x	x		x
slope_terrain	0.11	0.2233		x		

* = $p < 0.05$

The best subset results were examined to identify a variable subset that met the selection criteria: high increment in adjusted R^2 and significant incremental decrease in Mallow's Cp. A three-variable model was selected for estimating terminal woody canopy density for reclaimed mines. The variables were recovery time (Figure 6.5a), and leaf-on NDVI and leaf-off NDVI (Figure 6.6 a and b).

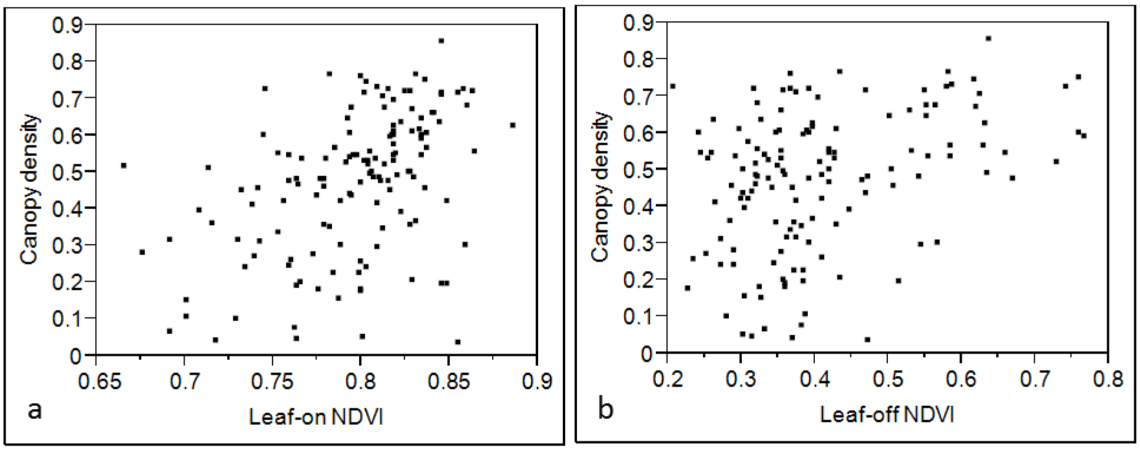

Figure 6.6. Leaf-off NDVI (a) and leaf-off NDVI (b), components of the final woody canopy cover prediction model, are both correlated with woody canopy density.

A standard least square linear regression model was built using the three parameters (Table 6.4 and Table 6.5 and Figure 6.7). Residuals were found to be normally distributed and randomly distributed around a mean of zero. The leave-one-out cross validation procedure yielded a predicted R^2 of 0.51.

Table 6.4. Parameter estimates obtained for the final model

Predictor	**Coefficient**	**Std. Error**	**T**	**P**	**VIF**
Intercept	-0.854	0.211	-4.04	0.000	
Recovery time	2.366	0.262	9	0.000	1.127
2009 NDVI	0.211	0.095	2.2	0.029	1.155
2008 NDVI	1.149	0.281	4.08	0.000	1.159

Table 6.5. Model result for final model with three predictors: recovery time, leaf-on NDVI and leaf-off NDVI.

Summary of fit	
R^2	0.541
Adj. R^2	0.531
RMSE	0.13
Pred. R^2	0.512
PRESS	2.433

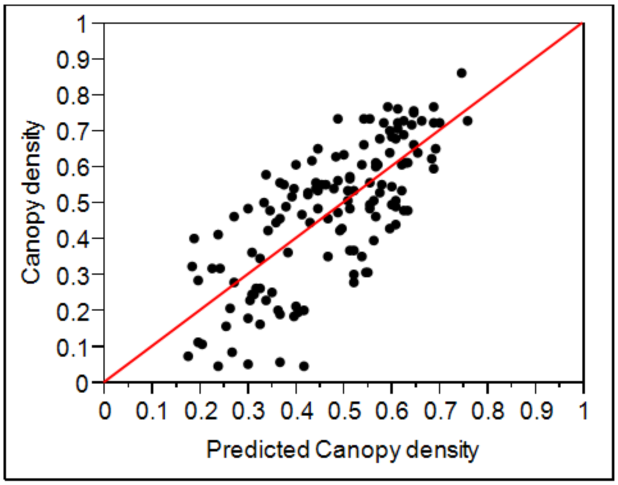

Figure 6.7. Actual vs. predicted canopy plot for the three-variable model (Table 6.5). Red line shows 1:1 correspondence.

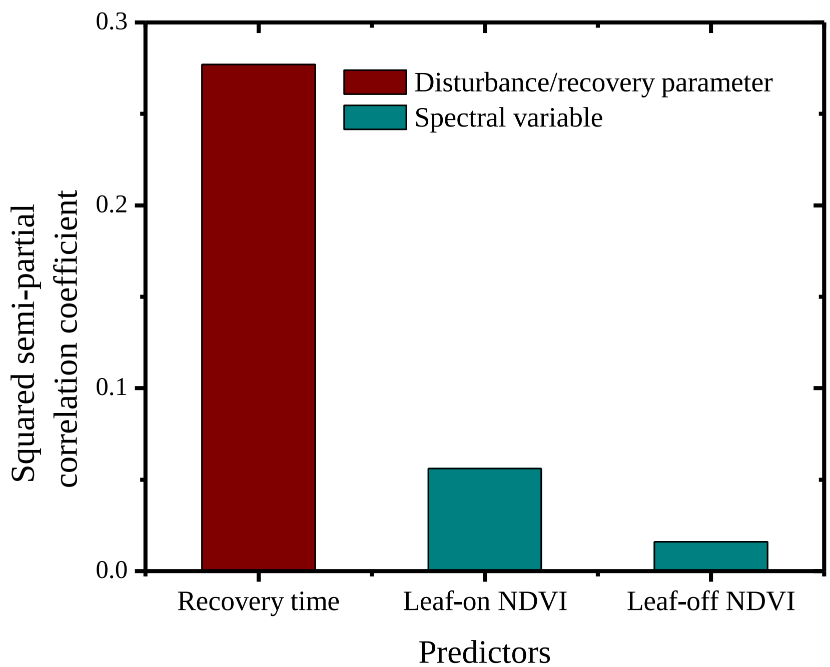

Figure 6.8. Unique contributions of each predictor in the model, as computed using the squared semi-partial correlation coefficient using type III SS.

The squared semi-partial correlation coefficient (using type III Sum of squares) that was calculated reveals the unique contribution of each parameter to the model: Recovery time contributes the maximum, followed by leaf-on NDVI and leaf-off NDVI (Figure 6.8).

ArcMap^{TM} Raster calculator was used to display the results from the empirical model and the results are shown in Figure 6.9 in the form of a woody canopy cover map.

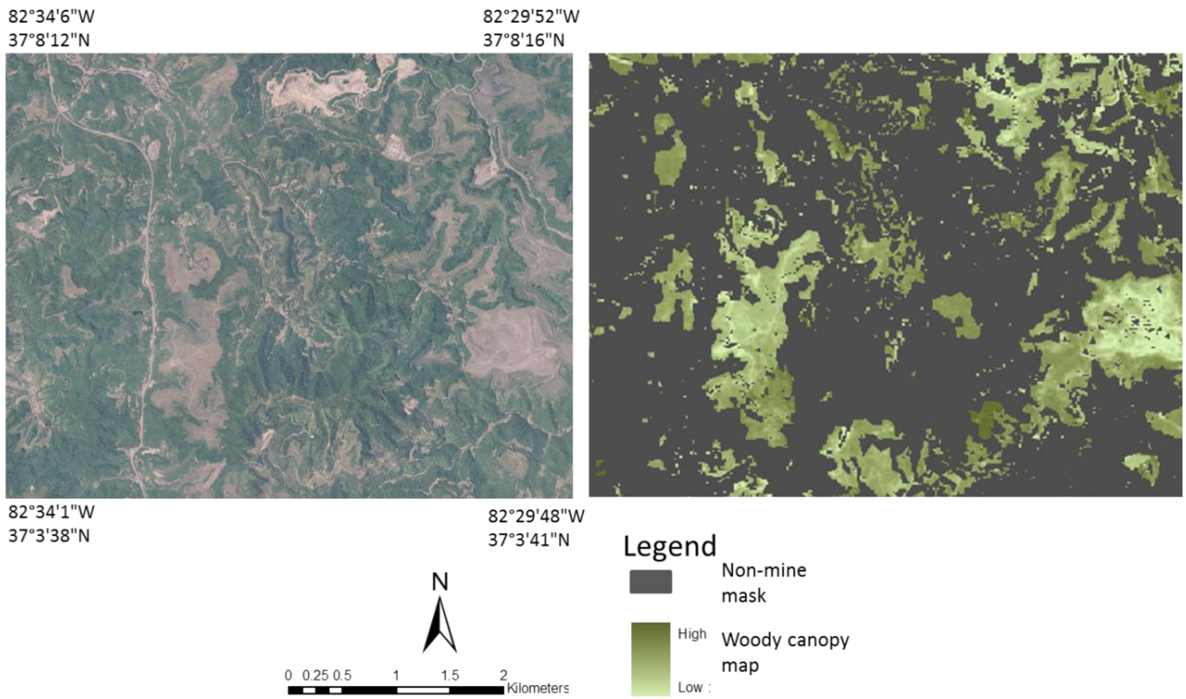

Figure 6.9. Woody canopy density for mines, as estimated by the final woody canopy cover prediction model (Table 6.4), with non-miend areas masked, and a NAIP aerial photo of the same area.

6.5. Discussion

The disturbance/recovery parameters employed in this work are useful metrics for disturbance analyses. Sen et al. (2011) found that they can be used to successfully identify mining disturbances by separating them from other landscape disturbances. Kennedy et al. (2007) showed that trajectory-derived parameters can be valuable in detecting disturbance, and in estimating both disturbance intensity and recovery rate. Parameters used in their work are year of disturbance, change in spectral value at disturbance, rate of spectral recovery, and summary statistics (F value and P of F value) that indicate model fit. Huang et al. (2010) used trajectory-based change detection to formulate the vegetation change tracker (VCT) algorithm which makes use of trajectory parameters such as disturbance year and disturbance magnitude to estimate disturbance, recovery slope, and R^2 of linear fit to the recovery profile to estimate recovery. They make two important observations about the parameters. First, the spectral recovery as represented by the recovery curve may not be synonymous with the ecological definitions of forest recovery, since spectral recovery occurs at a much faster rate than woody biomass accrual on the ground. This is particularly true for NDVI values which tend to saturate at higher biomass levels. Second, they state that they are unable to conclude that disturbance-recovery parameters are direct indicators of vegetation biophysical changes associated with disturbance and regeneration, reasoning that such a conclusion would require multitemporal measurements of biophysical changes which are very difficult to obtain. This is also true in case of mining disturbance and regeneration, where repeated measures of biophysical changes associated with woody vegetation regeneration are generally not obtained.

We used NDVI as the VI of choice for constructing the recovery trajectory, but found little indication of recovery parameter influence on current woody canopy estimation. This finding is surprising, given that, in 2008, leaf-on NDVI was highly correlated with woody canopy cover and that other researchers have found spectral recovery parameters to be indicative of actual recovery. It is possible that our results occurred because the fixed-time-period (7-year) and linear recovery indicators were not well matched with wide range and distribution of site ages included in this study.

Other researchers have used different indices, some of which might be tested for mined areas in future. Kennedy et al. (2007) used Landsat band 5; while Huang et al. (2010) used a forest likelihood measure, computed from Landsat bands 3, 5 and 7, to construct their trajectories. Gomez et al. (2011) used trajectories constructed from Tasseled Cap Angle index (Powell et al. 2010) to characterize forested landscape change and developed the Lagrangian second order polynomial of the TCA trajectories to study the recovery phase. In addition to our disturbance/recovery parameters, a second-order derivative, similar to the Gomez et al. (2011)

work might be an alternative way to analyze the recovery trajectory by estimating the incremental change in vegetation in consecutive years, instead of an absolute change in a given number of years. Several studies in the western Oregon (Cohen et al. 2001; Fiorella and Ripple 1993) found that Tasseled Cap wetness conveys most information, particularly about forest age class, since TC wetness is related to canopy shadowing, which increases with increase in canopy complexity with increasing time. In context of mines, where increasing canopy shadowing with time is more noticeable than canopy cover, particularly for more sparsely vegetated areas, TC wetness can prove to be a valuable metric for constructing trajectories to assess ecological restoration. Song et al. (2007) stated that TC wetness increases rapidly with stand age in the early years of regeneration. They caution against using this index for a longer duration study (>40 yrs), though that long recovery periods in not very common in mined lands.

However, in spite of these difficulties, these parameters, particularly the recovery time holds a lot of promise in predicting the future canopy density. The two spectral variables that proved important are the 2008 and 2009 NDVI. Since the 2008 is the leaf-on image, it represents the vegetated condition more closely than the leaf-off 2009. This is also reflected by their unique contributions to the model (calculated as squared semi-partials), where 2008 NDVI is higher than 2009 NDVI. The R^2 for the final model is less than that which has been achieved with an alternative modeling approach (Sen 2011). However, the results from this study can be used to inform that these three variables are important enough with considerable predictive power, and that future canopy cover estimation models can make use of these three variables add to their existing models.

The finding that recovery time, alone among disturbance/recovery parameters, is a significant contributor to the canopy prediction model highlights the fact that knowledge of the recovery time period (or the disturbance year, assuming that recovery started soon after) can contribute to woody canopy density estimation processes on reclaimed coal mine areas. This fact indicates that soils on these areas have been prepared to support plant cover, and generally lack significant plant-limiting properties, such as excessive compaction, high acidity, and the like. Other forms of severe landscape disturbances, where regulatory structures do not ensure surface properties favorable for plant growth, do not demonstrate comparable recovery (e.g., Faulkner et al. 2004).

Even on areas mined for coal under SMCRA, however, soil conditions are often far from ideal for forested ecosystem recovery (Angel et al. 2005; Simmons et al. 2008). Thus, much of the woody canopy detected by the photointerpretation procedures, and found here to be progressing with time, is likely comprised of non-native invasive, or a mix of invasive and native, woody species (Zipper et al. 2011).

Long-term monitoring of ecosystem recovery in disturbed landscapes is essential to evaluation of restoration success. Results of such analyses can provide guidance concerning the effectiveness of restoration procedures that have employed and/or needs for further restoration; and they can aid development of policies and practices intended to encourage beneficial reuse of such areas. Remote sensing can be a valuable and cost-effective tool if employed for such purposes over Appalachian areas that have been surface mined for coal, because such lands occur over a large region of eastern US, are often in locations that are difficult to access physically, and are not well characterized by existing data.

This study also highlights the limitations of Landsat remote-sensing data as an ecosystem assessment tool. On disturbed landscapes in naturally forested environments, development of woody canopy as a successor to the herbaceous-dominant ecosystems that commonly establish initially is an indicator that ecosystem development is progressing, and that the resources necessary to support plant species of greater stature and with greater resource demands than the herbaceous pioneers are present. However, the different types of woody canopy that may be present can lead to very different interpretations. Where recovering woody canopy is comprised of native forest trees, full and rapid canopy development would be an indication that recovery of ecosystem processes is progressing along a favorable trajectory. Where such recovery is comprised predominantly of non-native invasives, the greater likelihood is of progression towards an “arrested succession” state. As we have noted, Landsat-based recovery assessments are unable to detect which of these outcomes is occurring on individual mine sites. Such limitations could be overcome by employing Landsat in association with higher spectral resolution remote sensing or field-based assessments.

6.6. Conclusion

We have found that recovery time and two spectral parameters that serve as indicators of vegetation's presence derived from Landsat satellites – leaf-on and leaf-off NDVI – can be employed in modeling approaches to estimate woody canopy cover on coal mines reclaimed under SMCRA over a 25 year period in eastern USA. Our results show promise use of Landsat-derived multitemporal recovery metrics as a basis for development of more precise woody canopy cover estimating methods. Leaf-on NDVI was highly correlated with woody canopy cover. Given that full woody canopy cover development requires longer terms than 7 years, it is possible that NDVI-based recovery parameters calculated for longer terms would serve as better indicators of woody canopy development than the 7-year recovery parameters used here.

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Chapter 7 Conclusions

There is a vast land resource base that has been mined and reclaimed in Appalachian USA under the federal mine reclamation law. More than 600,000 hectares of coal-mined lands (Zipper et al. 2011b), an area equivalent to approximately 4 percent of the entire Appalachian coalfield, have been reclaimed in Appalachia since the federal mine reclamation law was established in 1977. Recently, reclamation practices intended to re-establish native forest have come into use on some coal-mined lands (Burger 2005; Zipper et al. 2011b). In past years, however, many of coal-mined lands were reclaimed to conditions that, although satisfying requirements of federal law, did not enable productive post-mining management for forest products or for other purposes (Angel et al. 2005; Simmons et al. 2008; Zipper et al. 2011a). Recent studies have documented that these lands do have potential for conversion into productive renewable resources, but such conversions often require active intervention and mitigation (Burger et al. 2011; Evans et al. 2010; Fields-Johnson et al. 2008; Skousen et al. 2009; Zipper et al. 2011a). Recent studies have also documented that woody canopy that does occur on reclaimed mined lands may be comprised of native forest trees, non-native invasives, or mixtures of these two woody vegetation types (Zipper et al. 2011a). Information on the status of these lands, including their locations, extents, and current vegetative cover is crucial for development of management strategies and policies that would enable these lands to be returned to environmentally sound conditions and productive uses. Unfortunately such information is lacking, or in publically inaccessible form. There is a strong need to conduct studies for better characterization of the mined land base.

We have developed methods to use satellite imagery to characterize the impacts of and recovery from surface coal mining in forested landscapes. In the first part of our study we have identified reclaimed mines by separating them from other forest-replacing disturbances. A trajectory-based change detection technique was employed using disturbance/recovery parameters to separate mined and reclaimed lands from other disturbances. Three disturbance-recovery parameters were used: disturbance minimum, recovery slope, and recovery maximum; and the two recovery parameters were computed for seven-year recovery periods. These parameters were found to be diagnostic of mining disturbances, and to enable separation of reclaimed mines from native forest and from other disturbances. Year of mining was also identified for the mines. This study has revealed that an object-based classification has better accuracies than pixel-based classifications for these purposes. It has also found, that of the three tested vegetation indices (NDVI, Tasseled cap Greenness-Brightness ratio TC G/B and band 3 inverse), TC G/B has the best accuracy for mined land identification. NDVI was the best performer for a pixel-based classification. This study has explored the use of trajectory based multitemporal change detection in highly disturbed Appalachian landscapes where dramatic landcover changes occur within short period of times. It has also revealed that disturbance/recovery parameters are diagnostic for mining/reclamation and can be successfully used to delineate such disturbances.

The second and third parts of the study focused on the recovery of woody vegetation in these disturbed ecosystems. In the second part, we have estimated the woody canopy cover in southwestern Virginia in 2008 (terminal year for the chronosequence used for mine-identification in chapter 4), looking at mines and non-mines together and separately. These models were constructed using a set of potential explanatory variables, both spectral- and terrain- related. We have identified variables that provide for satisfactory canopy cover estimation in mines and non-mining areas. We have also demonstrated that mines are very different from non-mines by their canopy cover and concluded that models developed separately for the mined areas performed better than a model developed for areas that combine mined and non-mined land areas.

In the third and final part, we have tested the utility of the disturbance/recovery trajectory parameters, developed in the first part of the study using the 1984-2008 Landsat image chronosequence, for predicting the terminal woody canopy cover density in the reclaimed mines. The parameters included: recovery time, disturbance minimum, recovery maximum and recovery slope; both recovery parameters were computed for seven-year recovery periods. The study has revealed that, only the recovery time has high predictive power, and the other disturbance-recovery parameters have negligible contribution to woody canopy prediction. This finding suggests that the period of vegetative recovery is an important influence on woody canopy density for reclaimed coal mines. We have also tested the utility of influential variables identified in Chapter 5 of the study as additional components of models that include years of recovery as woody canopy predictors. We found that leaf-on and leaf-off NDVI when added to recovery time based prediction model improve their predictive capability.

This research has answered many questions on the use of Landsat data to describe reclaimed mines in the Appalachian coal fields of southwestern Virginia. Results indicate that potential use of Landsat data to identify and characterize vegetation status on disturbed landscapes of the Appalachian coal fields' shows promise. However, the study has also opened doors for future research by suggesting additional questions:

- Could the mined land identification be done on an operational basis in a much larger spatial scale?
- How can woody canopy cover be better defined from a remote sensing perspective?
- How can native forest trees and non-native invasives be separated as components of the woody canopy cover class?
- What is the physical significance of the disturbance/recovery parameters?
- Is there use in creating a woody canopy trajectory (a temporal sequence of woody canopy estimate from all years in the image stack) to represent the vegetation developmental pattern? Or, do the disturbance/recovery parameters serve as adequate surrogates of the woody canopy development?
- Is the parameters' utility for woody canopy estimation limited by the pre-decided recovery time? Seven years was determined as optimal for mine identification. Would a different time period be more suitable for recovery characterization?

- Could the process of determining recovery slope and recovery maximum be changed, so as to enable these parameters' use for woody canopy recovery characterization?
- Are there other spectral indices that represent the vegetation dynamics in a reclaimed mined area?
- How can Landsat-based multispectral techniques be adapted so as to allow application in areas with frequent cloud cover, such as the Appalachian coalfields?

Long-term monitoring of ecosystem recovery in disturbed landscapes is essential to evaluation of restoration success. Remote sensing can be a valuable and cost-effective tool if employed for such purposes over Appalachian areas that have been surface mined for coal, because such lands occur over a large region of eastern US, are often in locations that are difficult to access physically, and are not well characterized by existing data.

On disturbed landscapes in naturally forested environments, development of woody canopy as a successor to the herbaceous-dominant ecosystems that commonly establish initially is an indicator that ecosystem development is progressing, and that the resources necessary to support plant species of greater stature and with greater resource demands than the herbaceous pioneers are present. However, the different types of woody canopy that may be present can lead to very different interpretations. Where recovering woody canopy is comprised of native forest trees, full and rapid canopy development would be an indication that recovery of ecosystem processes is progressing along a trajectory toward the system's pre-disturbance state. Where such recovering woody vegetation is comprised predominantly of non-native invasives, the greater likelihood is of progression towards either an "arrested succession" or a "novel ecosystem" state (Hobbs et al. 2006). A recent survey of post-SMCRA Appalachian coal surface mines has found that invasive woody vegetation occurs commonly on these areas, although some mines with replanted and/or naturally invading woody species were also found (Zipper et al. 2011a). With Landsat's spatial resolution of 30m, it is often difficult to detect which of these outcomes is occurring on individual mine sites. Such limitations could be overcome by employing

Landsat in association with higher spatial/spectral resolution remote sensing or field-based assessments.

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Appendices

Appendix A: Mine-identification code, for pixels (Chapter 4)

FORTRAN program to delineate disturbance and report disturbance/recovery parameters on a pixel basis.

```
Program:  MineID
    implicit none
    LOGICAL :: PixelNotWritten
    INTEGER, parameter :: S_LEN = 32, THREE_LINES = 198, NEG1 = -1
    INTEGER, parameter :: MAX_RECOVERY_TIME = 7
    INTEGER (KIND = 2) :: b    ! NumBands
    INTEGER (KIND = 2) :: MinRecoveryYears
    INTEGER (KIND = 2) :: RecoveryYear
    INTEGER (KIND = 2) :: YearMined = 0
    INTEGER (KIND = 8) :: Currx
    INTEGER (KIND = 8) :: NumRecoveryYears
    INTEGER (KIND = 8) :: NumRows, NumCols
    INTEGER (KIND = 8) :: i, j, k, l     ! Loop counters
    REAL (KIND = 4) :: Threshold
    REAL (KIND = 4) :: sxx
    REAL (KIND = 4) :: sxy
    REAL (KIND = 4) :: xm
    REAL (KIND = 4) :: ym
    REAL (KIND = 4) :: xsum
    REAL (KIND = 4) :: ysum
    REAL (KIND = 4) :: xres
    REAL (KIND = 4) :: yres
    REAL (KIND = 4) :: PixelSlope
    REAL (KIND = 4) :: CurrMax
    REAL (KIND = 4), ALLOCATABLE :: x (:,:)
    INTEGER (KIND = 2), ALLOCATABLE :: When (:)
    REAL (KIND = 4), ALLOCATABLE :: Slope (:)
    REAL (KIND = 4), ALLOCATABLE :: Low (:)
    REAL (KIND = 4), ALLOCATABLE :: High (:)
    CHARACTER (LEN = S_LEN) :: InputFileName
    CHARACTER (LEN = S_LEN) :: InputHeaderFileName
```

```
 CHARACTER (LEN = S_LEN) :: AbsoluteFileName
 CHARACTER (LEN = S_LEN) :: AbsoluteHeaderFileName
 CHARACTER (LEN = THREE_LINES) TempString
 PRINT *, "Input File Name: "
 read (unit = *, FMT = *) InputFileName
 PRINT *, "Absolute Threshold File Name: "
 read (unit = *, FMT = *) AbsoluteFileName
 PRINT *, "Absolute Threshold: "
 read (unit = *, FMT = *) Threshold
 PRINT *, "Minimum number of years since mining: "
 read (unit = *, FMT = *) MinRecoveryYears
 InputHeaderFileName = TRIM(InputFileName) // ".hdr"
 PRINT *, "InputHeaderFileName"
 PRINT *, "    ", InputHeaderFileName
 AbsoluteHeaderFileName = TRIM(AbsoluteFileName) //".hdr"
 PRINT *, "AbsoluteHeaderFileName"
 PRINT *, "    ", AbsoluteHeaderFileName
 open (unit = 13, file = InputHeaderFileName, &
            status = "old", action = "read")
 PRINT *, "Input header file successfully opened."
 open (unit = 14, file = AbsoluteHeaderFileName, &
            status = "replace", action = "write")
 open (unit = 21, file = "debug.txt", &
    status = "replace", action = "write")
 read (unit = 13, fmt = *) TempString
 write (unit = 14, fmt = *) TempString
 read (unit = 13, fmt = "(A)") TempString
 write (unit = 14, fmt = "(A)") TempString
 read (unit = 13, fmt = "(A)") TempString
 write (unit = 14, fmt = "(A)") TempString
 read (unit = 13, fmt = "(A10,I)") TempString, NumCols
 write (unit = 14, fmt = "(A10,I)") TRIM (TempString), NumCols
 PRINT *, TRIM (TempString), NumCols
 read (unit = 13, fmt = "(A10,I)") TempString, NumRows
 write (unit = 14, fmt = "(A10,I)") TRIM (TempString), NumRows
 PRINT *, TRIM (TempString), NumRows
 read (unit = 13, fmt = "(A10,I)") TempString, b
 write (unit = 14, fmt = "(A10,I)") TRIM (TempString), b
 PRINT *, TRIM(TempString), b
 CLOSE(13)
 CLOSE (14)
k = NumRows * NumCols
```

```
write (unit = *, FMT = *) "Input file names: "
write (unit = *, FMT = *) "    ", InputFileName
write (unit = *, FMT = *) "Number of Bands: "
write (unit = *, FMT = *) "    ", b
write (unit = *, FMT = *) "Output file names: "
write (unit = *, FMT = *) "    ", AbsoluteFileName
   ALLOCATE (x (k,b))
   ALLOCATE (When (k))
   ALLOCATE (Slope (k))
   ALLOCATE (Low (k))
ALLOCATE (High (k))
x = 0.0
When = 0
Slope = 0.0
Low = 0.0
High = 0.0
PixelNotWritten = .TRUE.
open (unit = 11, file = InputFileName, &
         form = "binary", status = "old", action = "read")
write (unit = *, fmt = *) "Reading input image into memory..."
ReadRawBandsLoop: do j = 1, b
   ReadRawPixelsLoop: do i = 1, k
                    read (unit = 11) x (i,j)
   end do ReadRawPixelsLoop

   end do ReadRawBandsLoop
   close (unit = 11)
   write (unit = *, fmt = *) "Input image read into memory."
MaskBackgroundPixelLoop: do i = 1, k
      MaskBackgroundYearLoop: do j = 1, b
                    AnyYearEqualsZero: if (x(i,j) .EQ. 0.0) then
                    x(i,:) = -1.0
            END if AnyYearEqualsZero
   end do MaskBackgroundYearLoop
   end do MaskBackgroundPixelLoop
PRINT *, "Calculating absolute thresholds and slopes"
LessThanFourTenthsAbs: do i = 1, k
      CurrMax = 0.0
   When(i) = MINLOC ( x(i,:), 1, ((x(i,:) .LT. Threshold) .AND. (x(i,:) .GT. 0.0) ) )
      if (PixelNotWritten) then
   write (unit = *, fmt = *) "First non-zero brightness value vector (pixel ", i, ") is "
            do j = 1, b
```

```
                PRINT *, x(i,j)
            end do
            PixelNotWritten = .FALSE.
    end if
    YearMined = When(i)
    LowValueOnlyIfMined: if (YearMined .GT. 0) then
            Low(i) = x(i,YearMined)
    END if LowValueOnlyIfMined
TrueSlope: if ( (YearMined .GT. 0) .AND. ( (b-YearMined) .GE.
MinRecoveryYears) ) then
            if (YearMined .EQ. 0) then
            PRINT *, "Should not be computing slopes with no mining!!!"
            STOP
            end if
            sxx = 0.0
            sxy = 0.0
            Currx = 0
            xm = 0.0
            ym = 0.0
            xsum = 0.0
            ysum = 0.0
            xres = 0.0
            yres = 0.0
            PixelSlope = 0.0
            FindSevenYearMax: do l = YearMined, YearMined +
MAX_RECOVERY_TIME
                FindMaxAfterMining: if (x(i,l) .GT. CurrMax) then
                   CurrMax = x(i,l)
                end if FindMaxAfterMining
                High(i) = CurrMax
                RecoveryYear = l
                 end do FindSevenYearMax
            NumRecoveryYears = RecoveryYear - YearMined
           CalculateSums: do l = YearMined, RecoveryYear
                Currx = Currx + 1
                xsum = xsum + Currx
                   ysum = ysum + x(i,l)
       end do CalculateSums
            xm = xsum / (NumRecoveryYears)
            ym = ysum / (NumRecoveryYears)
             Currx = 0
            ComputeSlopePrecursors: do l = YearMined, &
```

```
                    RecoveryYear
            Currx = Currx + 1
                    xres = Currx - xm
                    yres = x(i,l) - ym
                    sxx = sxx + (xres * xres)
            sxy = sxy + (xres * yres)
            end do ComputeSlopePrecursors
            PixelSlope = sxy / sxx
            Slope(i) = PixelSlope
        end if TrueSlope
          YearMined = 0
        END do LessThanFourTenthsAbs
      PRINT *, "Absolute processing completed."
      PRINT *, "First year set to zero for both absolute and difference."
      PRINT *, "Opening output files."
        open (unit = 10, file = AbsoluteFileName, &
            form = "binary", status = "replace", action = "write")
        write (unit = *, fmt = *) "Output image files opened."
        write (unit = *, fmt = *) "Writing output files."
      do i = 1, k
        write (unit = 10) REAL(When (i))
      END do
      do i = 1, k
          write (unit = 10) Slope(i)
      end do
      do i = 1, k
        write (unit = 10) Low(i)
      end do
      do i = 1, k
          write (unit = 10) High(i)
      END do
      PRINT *, "Absolute image successfully written."
      close (unit = 10)
        close (unit = 12)
      close (unit = 21)
        write (unit = *, fmt = *) "Output files written and closed."
        write (unit = *, fmt = *) "MineID complete."
end program MineID
```

Appendix B: Mine-identification code, for objects (Chapter 4)

FORTRAN program to delineate disturbance and report disturbance/recovery parameters on an object basis

Program: MineIDs

```
implicit none

INTEGER, parameter :: S_LEN = 32, NEG1 = -1
INTEGER, parameter :: MAX_RECOVERY_TIME = 7
INTEGER (KIND = 2) :: b    ! NumBands
INTEGER (KIND = 2) :: MinRecoveryYears
INTEGER (KIND = 2) :: RecoveryYear
INTEGER (KIND = 2) :: YearMined = 0
INTEGER (KIND = 8) :: Currx
INTEGER (KIND = 8) :: NumRecoveryYears
INTEGER (KIND = 8) :: i, k, l     ! Loop counters
REAL (KIND = 4) :: Threshold
REAL (KIND = 4) :: sxx
REAL (KIND = 4) :: sxy
REAL (KIND = 4) :: xm
REAL (KIND = 4) :: ym
REAL (KIND = 4) :: xsum
REAL (KIND = 4) :: ysum
REAL (KIND = 4) :: xres
REAL (KIND = 4) :: yres
REAL (KIND = 4) :: PixelSlope
REAL (KIND = 4) :: CurrMax

REAL (KIND = 4), ALLOCATABLE :: x (:,:)
INTEGER (KIND = 2), ALLOCATABLE :: When (:)
INTEGER (KIND = 8), ALLOCATABLE :: PolygonID (:)
REAL (KIND = 4), ALLOCATABLE :: Slope (:)
REAL (KIND = 4), ALLOCATABLE :: Low (:)
REAL (KIND = 4), ALLOCATABLE :: High (:)
CHARACTER (LEN = S_LEN) :: InputFileName
CHARACTER (LEN = S_LEN) :: OutputFileName
PRINT *, "Input File Name: "
read (unit = *, FMT = *) InputFileName
PRINT *, "Absolute Threshold File Name: "
```

```
read (unit = *, FMT = *) OutputFileName
PRINT *, "Absolute Threshold: "
read (unit = *, FMT = *) Threshold
PRINT *, "Minimum number of years since mining: "
read (unit = *, FMT = *) MinRecoveryYears
PRINT *, "Number of segments: "
read (unit = *, FMT = *) k
      PRINT *, "Number of bands (years with data): "
read (unit = *, FMT = *) b
open (unit = 21, file = "debug.txt", &
   status = "replace", action = "write")
write (unit = *, FMT = *) "Input file names: "
write (unit = *, FMT = *) "    ", InputFileName

write (unit = *, FMT = *) "Number of Bands: "
write (unit = *, FMT = *) "    ", b

write (unit = *, FMT = *) "Output file names: "
write (unit = *, FMT = *) "    ", OutputFileName

   ALLOCATE (x (k,b))
   ALLOCATE (When (k))
   ALLOCATE (PolygonID(k))
   ALLOCATE (Slope (k))
   ALLOCATE (Low (k))
ALLOCATE (High (k))

x = 0.0
When = 0
Slope = 0.0
Low = 0.0
High = 0.0
open (unit = 11, file = InputFileName, &
         form = "formatted", status = "old", action = "read")

write (unit = *, fmt = *) "Reading ASCII (.CSV) segment file into memory..."
ReadSegments: do i = 1, k

      read (11, *) PolygonID(i)
      read (11, *) x(i,1)
      read (11, *) x(i,2)
      read (11, *) x(i,3)
```

```
        read (11, *) x(i,4)
        read (11, *) x(i,5)
        read (11, *) x(i,6)
        read (11, *) x(i,7)
        read (11, *) x(i,8)
        read (11, *) x(i,9)
        read (11, *) x(i,10)
        read (11, *) x(i,11)
        read (11, *) x(i,12)
        read (11, *) x(i,13)
        read (11, *) x(i,14)
        read (11, *) x(i,15)
        read (11, *) x(i,16)
        read (11, *) x(i,17)
        read (11, *) x(i,18)
        read (11, *) x(i,19)
        read (11, *) x(i,20)
        read (11, *) x(i,21)
        read (11, *) x(i,22)
        read (11, *) x(i,23)

END do ReadSegments

    close (unit = 11)

    write (unit = *, FMT = *) "Input segments read into memory."

PRINT *, "Calculating absolute thresholds and slopes"

LessThanFourTenthsAbs: do i = 1, k

        CurrMax = 0.0

    When(i) = MINLOC ( x(i,:), 1, (x(i,:) .LT. Threshold))

        if (i .EQ. 16) then
                PRINT *, "Threshold = ", Threshold
                PRINT *, "x = ", x(i,:)
                PRINT *, "When(", i, ") = ", When(i)
        end if

        YearMined = When(i)
```

```
   LowValueOnlyIfMined: if (YearMined .GT. 0) then

         Low(i) = x(i,YearMined)
   END if LowValueOnlyIfMined

TrueSlope: if ( (YearMined .GT. 0) .AND. ( (b-YearMined) .GE.
MinRecoveryYears) ) then

         if (YearMined .EQ. 0) then

         PRINT *, "Should not be computing slopes with no mining!!!"
         STOP

         end if

         sxx = 0.0
         sxy = 0.0
         Currx = 0
         xm = 0.0
         ym = 0.0
         xsum = 0.0
         ysum = 0.0
         xres = 0.0
         yres = 0.0
         PixelSlope = 0.0


         FindSevenYearMax: do l = YearMined, YearMined +
MAX_RECOVERY_TIME

               FindMaxAfterMining: if (x(i,l) .GT. CurrMax) then

                  CurrMax = x(i,l)

               end if FindMaxAfterMining

               High(i) = CurrMax
               RecoveryYear = l

         end do FindSevenYearMax
```

```
NumRecoveryYears = RecoveryYear - YearMined

CalculateSums: do l = YearMined, RecoveryYear

    Currx = Currx + 1

    if (PolygonID(i) .EQ. 1535) then

        PRINT *, "Current x = ", Currx

    end if

    xsum = xsum + Currx

    if (PolygonID(i) .EQ. 1535) then

        PRINT *, "xsum = ", xsum

    end if


      ysum = ysum + x(i,l)

    if (PolygonID(i) .EQ. 1535) then

        PRINT *, "ysum = ", ysum
    end if

end do CalculateSums


                    xm = xsum / (NumRecoveryYears)
ym = ysum / (NumRecoveryYears)

if (PolygonID(i) .EQ. 1535) then

   PRINT *, "xsum = ", xsum
   PRINT *, "xm = ", xm
   PRINT *, "RecoveryYear - YearMined + 1 = ", (NumRecoveryYears)
   PRINT *, "ym = ", ym
end if
Currx = 0
```

```
            ComputeSlopePrecursors: do l = YearMined, &
                  RecoveryYear
            Currx = Currx + 1
                  xres = Currx - xm
                  yres = x(i,l) - ym
                  sxx = sxx + (xres * xres)
            sxy = sxy + (xres * yres)
            if (PolygonID(i) .EQ. 1535) then

              PRINT *, "Current x in compute slope precursors = ", Currx
              PRINT *, "xres = ", xres
              PRINT *, "yres = ", yres
              PRINT *, "sxx = ", sxx
              PRINT *, "sxy = ", sxy
            end if
            end do ComputeSlopePrecursors
            PixelSlope = sxy / sxx
            Slope(i) = PixelSlope

            if (PolygonID(i) .EQ. 1535) then

                PRINT *, "PixelSlope = ", PixelSlope
                PRINT *, "Slope(i) = ", Slope(i)
            end if

      end if TrueSlope

        YearMined = 0
      END do LessThanFourTenthsAbs

    PRINT *, "Processing completed."

    PRINT *, "Opening output files."

    open (unit = 10, file = OutputFileName, &
          form = "formatted", status = "replace", action = "write")

      write (unit = *, fmt = *) "Output file opened."
      write (unit = *, fmt = *) "Writing output file."

24 format(I6, ",", I4, ",", F9.3, ",", F9.3, ",", F9.3)
```

```
    WriteSegments: do i = 1, k

    write (10, 24) PolygonID(i), When (i), Slope(i),  Low(i), High(i)

    END do WriteSegments

    PRINT *, "Output segments successfully written."

    close (unit = 10)
    close (unit = 11)
    close (unit = 21)

      write (unit = *, fmt = *) "Output file written and closed."
      write (unit = *, fmt = *) "MineIDs complete."

end program MineIDs
```

Appendix C: Validation data points used in mine-identification (Chapter 4)

Validation points used in Chapter 4, with X and Y coordiantes (WGS 1984 UTM Zone 17N), landcover-type and -code used in the classification process.

Point No.	X	Y	Landcover	Landcover code
1	353731.7313	4110821.1022	Forest	1
2	350207.1487	4111465.5973	Forest	1
3	368635.6808	4108424.3860	Forest	1
4	371213.6612	4108525.0883	Forest	1
5	364728.4292	4101455.7826	Forest	1
6	357296.5949	4096138.6979	Forest	1
7	348132.6801	4099804.2639	Forest	1
8	343923.3214	4093319.0318	Forest	1
9	354779.0359	4109431.4096	Forest	1
10	344910.2045	4112533.0423	Forest	1
11	344467.1141	4107256.2386	Forest	1
12	342594.0502	4103409.4084	Forest	1
13	343802.4785	4099884.8257	Forest	1
14	347468.0445	4099461.8758	Forest	1
15	366823.0383	4103671.2345	Forest	1
16	361405.2513	4107175.6767	Forest	1
17	367004.3025	4112150.3733	Forest	1
18	356571.5379	4112714.3065	Forest	1
19	356954.2069	4103550.3917	Forest	1
20	362170.5892	4102059.9967	Forest	1
21	347926.5149	4105316.0398	Forest	1
22	351968.7687	4107034.2051	Forest	1
23	349258.7156	4107486.5723	Forest	1
24	347316.4417	4107889.1377	Forest	1
25	351314.8747	4110901.6640	Forest	1
26	356027.7452	4087619.2782	Forest	1
27	367789.7809	4086430.9903	Forest	1
28	371999.1396	4092493.2724	Forest	1

29	361223.9870	4086048.3213	Forest	1
30	344346.2713	4086028.1809	Forest	1
31	377641.4445	4109922.5441	Forest	1
32	373632.6039	4113499.0587	Forest	1
33	377169.8162	4106463.9366	Forest	1
34	373816.0149	4104642.9273	Forest	1
35	378361.9877	4101551.1417	Forest	1
40	343933.1216	4100555.4820	Forest	1
41	343055.3689	4102546.8015	Forest	1
42	340461.4133	4095118.6557	Forest	1
43	343893.8193	4093625.1661	Forest	1
44	343671.1059	4103542.4612	Forest	1
45	356221.6591	4101446.3355	Forest	1
46	353300.1837	4105075.2532	Forest	1
47	352605.8421	4100712.6914	Forest	1
48	352278.3224	4110263.1646	Forest	1
49	362103.9120	4107105.8751	Forest	1
50	355802.4339	4106948.6656	Forest	1
51	351020.6469	4105284.8658	Forest	1
52	350116.6927	4106319.8279	Forest	1
53	365667.3259	4108009.8293	Forest	1
54	364606.1622	4110564.4826	Forest	1
55	363073.3702	4100031.4505	Forest	1
56	353549.0987	4099546.7215	Forest	1
57	358212.9786	4107132.0767	Forest	1
58	351400.5697	4089786.6357	Forest	1
59	345688.6270	4087913.2233	Forest	1
60	363374.6883	4085568.1826	Forest	1
61	368890.1193	4085935.0046	Forest	1
62	374091.1314	4092708.1111	Forest	1
63	367422.8312	4090454.7758	Forest	1
64	375741.8305	4101472.5370	Forest	1
65	375925.2415	4098367.6507	Forest	1
66	367527.6375	4102677.8094	Forest	1
67	365824.5353	4103712.7715	Forest	1
68	364134.5339	4101603.5449	Forest	1
69	372767.9520	4108376.6513	Forest	1
70	378741.9105	4109005.4891	Forest	1

71	377824.8555	4110381.0716	Forest	1
72	367632.4438	4109188.9001	Forest	1
73	366597.4817	4109490.2182	Forest	1
74	370409.8105	4108127.7364	Forest	1
75	373095.4717	4109306.8072	Forest	1
76	373056.1693	4103647.2675	Forest	1
77	367213.2187	4113616.9658	Forest	1
78	375545.3187	4112398.5927	Forest	1
79	372951.3630	4111271.9251	Forest	1
80	358841.8163	4113197.7407	Forest	1
81	357164.9157	4113551.4619	Forest	1
82	361186.8570	4103987.8880	Forest	1
83	354007.6262	4110197.6606	Forest	1
84	355750.0307	4102638.5070	Forest	1
85	349645.0644	4110263.1646	Forest	1
86	344902.5798	4107760.9144	Forest	1
87	345138.3939	4103398.3526	Forest	1
88	349556.5084	4104845.1293	Forest	1
89	338234.2796	4088371.7508	Forest	1
90	345138.3939	4086537.6408	Forest	1
91	349003.1259	4088673.0689	Forest	1
92	351059.9493	4087323.6879	Forest	1
93	339505.0559	4090546.4813	Forest	1
94	350024.9872	4091660.0482	Forest	1
95	346592.5812	4093245.2433	Forest	1
96	354177.9364	4093887.1818	Forest	1
97	352789.2531	4087402.2927	Forest	1
98	353601.5018	4101289.1260	Forest	1
99	364252.4410	4101891.7622	Forest	1
100	360898.6397	4096232.2225	Forest	1
101	353915.9207	4093441.7551	Forest	1
102	355157.6172	4106719.0711	Forest	1
103	350748.4086	4106892.3587	Forest	1
104	351480.0677	4103959.3044	Forest	1
105	356184.5071	4101732.2370	Forest	1
106	356685.1159	4104639.6190	Forest	1
107	354304.0149	4105255.7529	Forest	1
108	354894.4766	4104575.4384	Forest	1

109	353771.3158	4103599.8930	Forest	1
110	360215.0500	4107213.2618	Forest	1
111	356659.4437	4106366.0777	Forest	1
112	350754.8267	4103991.3947	Forest	1
113	365984.8876	4104260.9533	Forest	1
114	363449.7532	4099986.5241	Forest	1
115	356620.9353	4100827.2902	Forest	1
116	366485.4965	4103638.4013	Forest	1
117	368160.6106	4102226.4277	Forest	1
118	367018.1956	4102252.1000	Forest	1
119	365811.6000	4107174.7535	Forest	1
120	361376.7192	4106905.1949	Forest	1
121	366036.2321	4109202.8610	Forest	1
122	361575.6791	4108214.4795	Forest	1
123	366530.4229	4106167.1177	Forest	1
124	366504.7506	4105108.1375	Forest	1
125	369726.6177	4108638.0716	Forest	1
126	371016.6482	4107348.0411	Forest	1
127	368359.5705	4108394.1852	Forest	1
128	364579.3321	4108849.8676	Forest	1
129	364489.4792	4113612.0696	Forest	1
130	370291.4072	4109100.1720	Forest	1
131	369014.2129	4108548.2187	Forest	1
132	363276.4655	4109902.4298	Forest	1
133	358886.5111	4111526.1994	Forest	1
134	360965.9632	4113464.4541	Forest	1
135	357923.8019	4111782.9219	Forest	1
136	364412.4625	4112598.0158	Forest	1
137	359534.7354	4109138.6804	Forest	1
138	363635.8770	4108265.8240	Forest	1
139	357590.0626	4108131.0447	Forest	1
140	356036.8917	4106199.2080	Forest	1
141	358032.9089	4105987.4120	Forest	1
142	357397.5208	4104633.2009	Forest	1
143	353488.9211	4104889.9234	Forest	1
144	353437.5766	4106045.1746	Forest	1
145	362037.7795	4105493.2212	Forest	1
146	361466.5720	4104447.0771	Forest	1

147	359104.7252	4107822.9777	Forest	1
148	350613.6293	4111340.0756	Forest	1
149	351127.0743	4109318.3861	Forest	1
150	348559.8495	4108798.5231	Forest	1
151	352243.8171	4106712.6530	Forest	1
152	354753.2793	4110114.2258	Forest	1
153	350741.9906	4111680.2329	Forest	1
154	345729.4842	4113329.6748	Forest	1
155	350196.4553	4113624.9057	Forest	1
156	353379.8140	4113105.0427	Forest	1
157	344484.3802	4107694.6165	Forest	1
158	344298.2564	4105371.2781	Forest	1
159	345312.3102	4104421.4049	Forest	1
160	345376.4908	4103920.7961	Forest	1
161	343431.8180	4101289.3907	Forest	1
162	343573.0154	4100859.3805	Forest	1
163	341891.4832	4103452.2775	Forest	1
164	342411.3462	4100891.4708	Forest	1
165	348110.5852	4100172.6479	Forest	1
166	347892.3711	4101533.2770	Forest	1
167	344195.5674	4100127.7215	Forest	1
168	341448.6369	4102585.8392	Forest	1
169	348624.0301	4099627.1126	Forest	1
170	344279.0022	4099242.0289	Forest	1
171	348155.5116	4098901.8716	Forest	1
172	351396.6329	4098407.6809	Forest	1
173	348643.2843	4092900.9838	Forest	1
174	347109.3675	4089146.4175	Forest	1
175	344676.9221	4093497.8635	Forest	1
176	351191.2549	4092503.0639	Forest	1
177	355433.5938	4087323.6879	Forest	1
178	357397.5208	4083947.7874	Forest	1
179	356421.9754	4083100.6032	Forest	1
180	352513.3757	4084807.8077	Forest	1
181	356332.1225	4085436.7777	Forest	1
182	359303.6852	4083338.0715	Forest	1
183	366517.5868	4084281.5266	Forest	1
184	367326.2626	4083453.5966	Forest	1

185	361383.1372	4082927.3155	Forest	1
186	363757.8201	4086136.3465	Forest	1
187	367634.3295	4086996.3668	Forest	1
188	370901.1231	4086450.8315	Forest	1
189	362050.6157	4088061.7651	Forest	1
190	362377.9368	4086104.2562	Forest	1
191	366061.9044	4087310.8518	Forest	1
192	364688.4391	4084268.6905	Forest	1
193	367242.8278	4085776.9350	Forest	1
194	373474.7659	4086104.2562	Forest	1
195	372274.5883	4084320.0350	Forest	1
196	368356.8422	4083186.1724	Forest	1
197	375816.4242	4084673.4770	Forest	1
198	367791.8970	4085342.1876	Forest	1
199	377142.3159	4097148.3885	Forest	1
200	360032.5482	4105242.0927	Forest	1
201	349817.4173	4111444.9599	Forest	1
202	364679.0406	4104691.5098	Mine	2
203	363305.4178	4106852.9457	Mine	2
204	361224.7832	4090470.4731	Mine	2
205	349367.1858	4091823.8956	Mine	2
206	350619.6067	4103519.8903	Mine	2
207	354235.4669	4106953.9474	Mine	2
208	364524.7529	4105233.6745	Mine	2
209	364643.5676	4109233.7696	Mine	2
210	364009.8892	4109458.1974	Mine	2
211	365937.3277	4110619.9411	Mine	2
212	374016.7276	4108573.6879	Mine	2
213	358363.3771	4103812.1920	Mine	2
214	358387.4600	4106051.9091	Mine	2
215	360771.6751	4105883.3283	Mine	2
216	360506.7623	4102720.4302	Mine	2
217	352463.0468	4100970.4003	Mine	2
218	352198.1341	4103178.0068	Mine	2
219	352318.5490	4102720.4302	Mine	2
220	350761.1829	4103539.2515	Mine	2
221	355168.3683	4104446.3771	Mine	2
222	351893.0830	4105835.1623	Mine	2

223	354638.5427	4107665.4688	Mine	2
224	354991.7598	4103948.6622	Mine	2
225	359912.7155	4107496.8880	Mine	2
226	362746.4795	4106469.3475	Mine	2
227	349565.0615	4098602.2405	Mine	2
228	349637.3105	4100432.5470	Mine	2
229	357103.0344	4101452.0599	Mine	2
230	352430.9362	4102688.3195	Mine	2
231	346490.4677	4092846.4082	Mine	2
232	345631.5080	4090100.9484	Mine	2
233	347951.5018	4093376.2337	Mine	2
234	345864.3102	4088944.9653	Mine	2
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610	354630.1574	4088395.5151	Urban	3
611	355053.3935	4088788.2083	Urban	3
612	353946.5802	4088842.0219	Urban	3

Appendix D: All sample points used in Chapter 5 and their originating grids

Landcover	Point No.	X	Y	Co.	PROJID	Sampling Grid
mine	4	1221120	1695420	27	51-27-4	4x
mine	7	1224540	1692360	27	51-27-7	4x
mine	15	1221060	1688430	27	51-27-15	4x
mine	25	1215030	1685070	27	51-27-25	4x
mine	33	1215870	1682550	27	51-27-33	4x
mine	48	1209840	1679160	27	51-27-48	4x
mine	49	1221870	1678920	27	51-27-49	4x
mine	58	1229580	1677300	27	51-27-58	4x
mine	65	1213260	1676100	27	51-27-65	4x
mine	114	1232130	1669740	27	51-27-114	4x
mine	139	1223520	1666920	27	51-27-139	4x
mine	159	1212330	1664640	27	51-27-159	4x
mine	161	1224360	1664400	27	51-27-161	4x
mine	172	1208010	1663200	27	51-27-172	4x
mine	183	1225200	1661880	27	51-27-183	4x
mine	194	1208880	1660710	27	51-27-194	4x
mine	254	1215690	1654590	27	51-27-254	4x
mine	358	1223400	1645950	27	51-27-358	4x
mine	234	1195950	1656450	51	51-51-234	4x
mine	245	1201110	1655340	51	51-51-245	4x
mine	278	1204530	1652280	51	51-51-278	4x
mine	279	1183050	1652190	51	51-51-279	4x
mine	286	1185630	1651650	51	51-51-286	4x
mine	340	1206210	1647270	51	51-51-340	4x
mine	435	1206180	1640280	51	51-51-435	4x
mine	508	1198410	1634910	51	51-51-508	4x
mine	418	1222500	1641480	167	51-167-418	4x
mine	450	1211310	1639170	167	51-167-450	4x
mine	464	1237950	1638180	167	51-167-464	4x
mine	523	1203570	1633830	167	51-167-523	4x

mine	552	1235340	1631730	167	51-167-552	4x
mine	574	1209540	1630230	167	51-167-574	4x
mine	674	1214670	1622130	167	51-167-674	4x
mine	367	1182990	1645200	195	51-195-367	4x
mine	383	1166670	1644000	195	51-195-383	4x
mine	394	1181280	1643220	195	51-195-394	4x
mine	412	1176960	1641810	195	51-195-412	4x
mine	420	1179540	1641270	195	51-195-420	4x
mine	445	1165800	1639500	195	51-195-445	4x
mine	453	1168350	1638960	195	51-195-453	4x
mine	456	1180380	1638750	195	51-195-456	4x
mine	460	1170930	1638420	195	51-195-460	4x
mine	487	1169220	1636440	195	51-195-487	4x
mine	504	1186380	1635150	195	51-195-504	4x
mine	506	1164900	1635030	195	51-195-506	4x
mine	514	1167480	1634490	195	51-195-514	4x
mine	521	1170060	1633950	195	51-195-521	4x
mine	527	1194090	1633500	195	51-195-527	4x
mine	541	1165740	1632510	195	51-195-541	4x
mine	547	1189800	1632090	195	51-195-547	4x
mine	548	1168320	1631970	195	51-195-548	4x
mine	553	1158870	1631640	195	51-195-553	4x
mine	569	1164030	1630560	195	51-195-569	4x
mine	571	1197540	1630440	195	51-195-571	4x
mine	576	1166610	1629990	195	51-195-576	4x
mine	582	1157160	1629660	195	51-195-582	4x
mine	589	1159710	1629120	195	51-195-589	4x
mine	598	1195800	1628490	195	51-195-598	4x
mine	608	1155420	1627710	195	51-195-608	4x
mine	611	1167450	1627500	195	51-195-611	4x
mine	617	1191480	1627050	195	51-195-617	4x
mine	629	1163130	1626060	195	51-195-629	4x
mine	638	1177740	1625310	195	51-195-638	4x
mine	639	1156260	1625190	195	51-195-639	4x
mine	658	1164000	1623570	195	51-195-658	4x
mine	695	1160520	1619610	195	51-195-695	4x
mine	1296	1231260	1669920	27	51-27-1296	9x
mine	1310	1226730	1678680	27	51-27-1310	9x

mine	1333	1234680	1664550	27	51-27-1333	9x
mine	1340	1233510	1663230	27	51-27-1340	9x
mine	1350	1230060	1659300	27	51-27-1350	9x
mine	1352	1228380	1668990	27	51-27-1352	9x
mine	1421	1227180	1658370	27	51-27-1421	9x
mine	1431	1223730	1654440	27	51-27-1431	9x
mine	1433	1221450	1656480	27	51-27-1433	9x
mine	1450	1218000	1657200	27	51-27-1450	9x
mine	1594	1220550	1697100	27	51-27-1594	9x
mine	1620	1213620	1689240	27	51-27-1620	9x
mine	1638	1214700	1676580	27	51-27-1638	9x
mine	1647	1208970	1679340	27	51-27-1647	9x
mine	1655	1222650	1667100	27	51-27-1655	9x
mine	1656	1221540	1670460	27	51-27-1656	9x
mine	1670	1221480	1661130	27	51-27-1670	9x
mine	1692	1208340	1667040	27	51-27-1692	9x
mine	1765	1199670	1654890	51	51-51-1765	9x
mine	1771	1216800	1646580	51	51-51-1771	9x
mine	1772	1217370	1644900	27	51-27-1772	9x
mine	1774	1215090	1646940	51	51-51-1774	9x
mine	1775	1213380	1647300	51	51-51-1775	9x
mine	1781	1213350	1642650	51	51-51-1781	9x
mine	1784	1211640	1643010	51	51-51-1784	9x
mine	1808	1207590	1640760	51	51-51-1808	9x
mine	1822	1201320	1645200	51	51-51-1822	9x
mine	1849	1189320	1647750	51	51-51-1849	9x
mine	1896	1200660	1628220	195	51-195-1896	9x
mine	1901	1196070	1627650	195	51-195-1901	9x
mine	1953	1195500	1624650	195	51-195-1953	9x
mine	2217	1185900	1653120	51	51-51-2217	9x
mine	2219	1183620	1655160	51	51-51-2219	9x
mine	2226	1181880	1650870	51	51-51-2226	9x
mine	2230	1179030	1649940	195	51-195-2230	9x
mine	2234	1181850	1646220	195	51-195-2234	9x
mine	2238	1184670	1637850	195	51-195-2238	9x
mine	2250	1180140	1646580	195	51-195-2250	9x
mine	2253	1177830	1643970	195	51-195-2253	9x
mine	2254	1176720	1647300	195	51-195-2254	9x

mine	2266	1192680	1633020	195	51-195-2266	9x
mine	2274	1184100	1634850	195	51-195-2274	9x
mine	2275	1188660	1630770	195	51-195-2275	9x
mine	2288	1186320	1623480	195	51-195-2288	9x
mine	2290	1181820	1636890	195	51-195-2290	9x
mine	2292	1181220	1633890	195	51-195-2292	9x
mine	2293	1180080	1637250	195	51-195-2293	9x
mine	2296	1184640	1628520	195	51-195-2296	9x
mine	2303	1176630	1633320	195	51-195-2303	9x
mine	2312	1175520	1636680	195	51-195-2312	9x
mine	2314	1171500	1639080	195	51-195-2314	9x
mine	2315	1172070	1637400	195	51-195-2315	9x
mine	2317	1169790	1639440	195	51-195-2317	9x
mine	2326	1173180	1629390	195	51-195-2326	9x
mine	2328	1171470	1629750	195	51-195-2328	9x
mine	2331	1169160	1627140	195	51-195-2331	9x
mine	2333	1168080	1639800	195	51-195-2333	9x
mine	2334	1166370	1640160	195	51-195-2334	9x
mine	2335	1166940	1638480	195	51-195-2335	9x
mine	2336	1168620	1633470	195	51-195-2336	9x
mine	2337	1169190	1631790	195	51-195-2337	9x
mine	2339	1166910	1633830	195	51-195-2339	9x
mine	2340	1165200	1634190	195	51-195-2340	9x
mine	2638	1166280	1626180	195	51-195-2638	9x
mine	2639	1166850	1624500	195	51-195-2639	9x
mine	2642	1162860	1626900	195	51-195-2642	9x
mine	2643	1161150	1627260	195	51-195-2643	9x
mine	2644	1161720	1625580	195	51-195-2644	9x
mine	2665	1154850	1627050	195	51-195-2665	9x
mine	2666	1159410	1622970	195	51-195-2666	9x
mixed	14	1218510	1689000	27	51-27-14	4x
mixed	19	1216770	1687020	27	51-27-19	4x
mixed	29	1210740	1683630	27	51-27-29	4x
mixed	57	1217550	1677510	27	51-27-57	4x
mixed	81	1202070	1673820	27	51-27-81	4x
mixed	117	1222680	1669440	27	51-27-117	4x
mixed	123	1203750	1668780	27	51-27-123	4x
mixed	132	1208910	1667700	27	51-27-132	4x

mixed	146	1216620	1666050	27	51-27-146	4x
mixed	181	1213170	1662120	27	51-27-181	4x
mixed	311	1217400	1649550	27	51-27-311	4x
mixed	237	1186500	1656120	51	51-51-237	4x
mixed	243	1189080	1655580	51	51-51-243	4x
mixed	252	1182210	1654710	51	51-51-252	4x
mixed	260	1196790	1653930	51	51-51-260	4x
mixed	272	1201950	1652850	51	51-51-272	4x
mixed	293	1188180	1651080	51	51-51-293	4x
mixed	329	1213080	1648140	51	51-51-329	4x
mixed	333	1203630	1647810	51	51-51-333	4x
mixed	334	1182150	1647720	51	51-51-334	4x
mixed	336	1215660	1647600	51	51-51-336	4x
mixed	337	1194180	1647480	51	51-51-337	4x
mixed	347	1208790	1646730	51	51-51-347	4x
mixed	359	1201920	1645860	51	51-51-359	4x
mixed	362	1213920	1645620	51	51-51-362	4x
mixed	374	1185570	1644660	51	51-51-374	4x
mixed	385	1200180	1643880	51	51-51-385	4x
mixed	393	1202760	1643340	51	51-51-393	4x
mixed	415	1188990	1641600	51	51-51-415	4x
mixed	427	1203600	1640820	51	51-51-427	4x
mixed	439	1196730	1639950	51	51-51-439	4x
mixed	442	1208730	1639740	51	51-51-442	4x
mixed	443	1187280	1639620	51	51-51-443	4x
mixed	447	1199280	1639410	51	51-51-447	4x
mixed	466	1194990	1637970	51	51-51-466	4x
mixed	469	1207020	1637760	51	51-51-469	4x
mixed	493	1193250	1636020	51	51-51-493	4x
mixed	543	1199250	1632420	51	51-51-543	4x
mixed	284	1228590	1651830	167	51-167-284	4x
mixed	291	1231140	1651290	167	51-167-291	4x
mixed	297	1233720	1650750	167	51-167-297	4x
mixed	303	1236300	1650210	167	51-167-303	4x
mixed	361	1235430	1645710	167	51-167-361	4x
mixed	403	1217340	1642560	167	51-167-403	4x
mixed	458	1213890	1638630	167	51-167-458	4x
mixed	472	1219050	1637550	167	51-167-472	4x

mixed	476	1209600	1637220	167	51-167-476	4x
mixed	511	1210440	1634700	167	51-167-511	4x
mixed	519	1213020	1634160	167	51-167-519	4x
mixed	327	1179570	1648260	195	51-195-327	4x
mixed	352	1177860	1646280	195	51-195-352	4x
mixed	371	1173540	1644870	195	51-195-371	4x
mixed	386	1178700	1643760	195	51-195-386	4x
mixed	428	1182120	1640700	195	51-195-428	4x
mixed	433	1172670	1640400	195	51-195-433	4x
mixed	436	1184700	1640160	195	51-195-436	4x
mixed	479	1166640	1637010	195	51-195-479	4x
mixed	482	1178670	1636770	195	51-195-482	4x
mixed	490	1181220	1636230	195	51-195-490	4x
mixed	494	1171770	1635900	195	51-195-494	4x
mixed	497	1183800	1635690	195	51-195-497	4x
mixed	501	1174350	1635360	195	51-195-501	4x
mixed	509	1176930	1634820	195	51-195-509	4x
mixed	524	1182090	1633710	195	51-195-524	4x
mixed	528	1172640	1633380	195	51-195-528	4x
mixed	533	1163190	1633050	195	51-195-533	4x
mixed	539	1187220	1632630	195	51-195-539	4x
mixed	561	1161450	1631100	195	51-195-561	4x
mixed	578	1200090	1629900	195	51-195-578	4x
mixed	584	1169160	1629450	195	51-195-584	4x
mixed	587	1181190	1629240	195	51-195-587	4x
mixed	592	1171740	1628910	195	51-195-592	4x
mixed	615	1158000	1627170	195	51-195-615	4x
mixed	623	1160580	1626600	195	51-195-623	4x
mixed	631	1196640	1625970	195	51-195-631	4x
mixed	635	1165710	1625520	195	51-195-635	4x
mixed	637	1199220	1625430	195	51-195-637	4x
mixed	649	1170870	1624440	195	51-195-649	4x
mixed	664	1166550	1623000	195	51-195-664	4x
mixed	669	1157100	1622670	195	51-195-669	4x
mixed	678	1162260	1621590	195	51-195-678	4x
mixed	690	1157970	1620180	195	51-195-690	4x
mixed	705	1156230	1618200	195	51-195-705	4x
mixed	739	1163070	1612080	195	51-195-739	4x

mixed	1304	1223850	1673070	27	51-27-1304	9x
mixed	1315	1221600	1679760	27	51-27-1315	9x
mixed	1316	1220430	1678470	27	51-27-1316	9x
mixed	1332	1234110	1666230	27	51-27-1332	9x
mixed	1337	1235220	1662870	27	51-27-1337	9x
mixed	1354	1229520	1665630	27	51-27-1354	9x
mixed	1432	1222560	1653120	27	51-27-1432	9x
mixed	1449	1220250	1645830	27	51-27-1449	9x
mixed	1617	1215900	1687200	27	51-27-1617	9x
mixed	1622	1218180	1685160	27	51-27-1622	9x
mixed	1625	1216470	1685520	27	51-27-1625	9x
mixed	1626	1215330	1684230	27	51-27-1626	9x
mixed	1627	1213050	1686270	27	51-27-1627	9x
mixed	1657	1222080	1668780	27	51-27-1657	9x
mixed	1689	1210050	1666680	27	51-27-1689	9x
mixed	1690	1210620	1665000	27	51-27-1690	9x
mixed	1701	1206090	1673730	27	51-27-1701	9x
mixed	1704	1203780	1671120	27	51-27-1704	9x
mixed	1724	1211160	1663320	27	51-27-1724	9x
mixed	1730	1213410	1656630	27	51-27-1730	9x
mixed	1800	1207620	1645410	51	51-51-1800	9x
mixed	1805	1209330	1640370	51	51-51-1805	9x
mixed	1810	1204740	1639800	51	51-51-1810	9x
mixed	1813	1203030	1640160	51	51-51-1813	9x
mixed	1828	1200750	1642200	51	51-51-1828	9x
mixed	1831	1200150	1639230	51	51-51-1831	9x
mixed	1834	1201290	1635870	51	51-51-1834	9x
mixed	1836	1199010	1637910	51	51-51-1836	9x
mixed	1892	1197810	1631940	195	51-195-1892	9x
mixed	1899	1198350	1625610	195	51-195-1899	9x
mixed	2215	1187070	1654440	51	51-51-2215	9x
mixed	2216	1185360	1654800	51	51-51-2216	9x
mixed	2224	1185870	1648470	51	51-51-2224	9x
mixed	2225	1183590	1650510	51	51-51-2225	9x
mixed	2229	1180170	1651230	51	51-51-2229	9x
mixed	2231	1183590	1645860	51	51-51-2231	9x
mixed	2236	1185270	1640820	195	51-195-2236	9x
mixed	2239	1183560	1641180	195	51-195-2239	9x

mixed	2244	1178970	1640610	195	51-195-2244	9x
mixed	2251	1178430	1646940	195	51-195-2251	9x
mixed	2256	1173840	1646370	195	51-195-2256	9x
mixed	2268	1190400	1635060	195	51-195-2268	9x
mixed	2271	1188090	1632450	195	51-195-2271	9x
mixed	2287	1185750	1625160	195	51-195-2287	9x
mixed	2291	1182360	1635210	195	51-195-2291	9x
mixed	2307	1173810	1641690	195	51-195-2307	9x
mixed	2313	1173780	1637040	195	51-195-2313	9x
mixed	2319	1173210	1634040	195	51-195-2319	9x
mixed	2321	1172610	1631070	195	51-195-2321	9x
mixed	2330	1170300	1628430	195	51-195-2330	9x
mixed	2342	1162320	1633230	195	51-195-2342	9x
mixed	2344	1180050	1627920	195	51-195-2344	9x
mixed	2392	1168560	1624140	195	51-195-2392	9x
mixed	2636	1163460	1629900	195	51-195-2636	9x
mixed	2637	1161720	1630260	195	51-195-2637	9x
mixed	2641	1164570	1626540	195	51-195-2641	9x
mixed	2646	1159440	1627620	195	51-195-2646	9x
mixed	2647	1158270	1626330	195	51-195-2647	9x
mixed	2651	1161690	1620930	195	51-195-2651	9x
mixed	2668	1158240	1621650	195	51-195-2668	9x
mixed	2669	1157100	1620360	195	51-195-2669	9x
non-mine	1	1224570	1699350	27	51-27-1	4x
non-mine	2	1222860	1697400	27	51-27-2	4x
non-mine	3	1225440	1696830	27	51-27-3	4x
non-mine	5	1219380	1693470	27	51-27-5	4x
non-mine	6	1221960	1692900	27	51-27-6	4x
non-mine	8	1217670	1691490	27	51-27-8	4x
non-mine	9	1220220	1690950	27	51-27-9	4x
non-mine	10	1222800	1690410	27	51-27-10	4x
non-mine	11	1225380	1689840	27	51-27-11	4x
non-mine	12	1215930	1689540	27	51-27-12	4x
non-mine	13	1227960	1689300	27	51-27-13	4x
non-mine	16	1223640	1687890	27	51-27-16	4x
non-mine	17	1214190	1687560	27	51-27-17	4x
non-mine	18	1226220	1687350	27	51-27-18	4x
non-mine	20	1228800	1686780	27	51-27-20	4x

non-mine	21	1219350	1686480	27	51-27-21	4x
non-mine	22	1221930	1685910	27	51-27-22	4x
non-mine	23	1212450	1685610	27	51-27-23	4x
non-mine	24	1224480	1685370	27	51-27-24	4x
non-mine	26	1227060	1684830	27	51-27-26	4x
non-mine	27	1217610	1684500	27	51-27-27	4x
non-mine	28	1220190	1683960	27	51-27-28	4x
non-mine	30	1222770	1683420	27	51-27-30	4x
non-mine	31	1213290	1683090	27	51-27-31	4x
non-mine	32	1225320	1682850	27	51-27-32	4x
non-mine	34	1227900	1682310	27	51-27-34	4x
non-mine	35	1218450	1682010	27	51-27-35	4x
non-mine	36	1230480	1681770	27	51-27-36	4x
non-mine	37	1209000	1681680	27	51-27-37	4x
non-mine	38	1221030	1681440	27	51-27-38	4x
non-mine	39	1211580	1681140	27	51-27-39	4x
non-mine	40	1223610	1680900	27	51-27-40	4x
non-mine	41	1214160	1680570	27	51-27-41	4x
non-mine	42	1226190	1680360	27	51-27-42	4x
non-mine	43	1216710	1680030	27	51-27-43	4x
non-mine	44	1228740	1679790	27	51-27-44	4x
non-mine	45	1207260	1679700	27	51-27-45	4x
non-mine	46	1219290	1679490	27	51-27-46	4x
non-mine	47	1231320	1679250	27	51-27-47	4x
non-mine	50	1233900	1678710	27	51-27-50	4x
non-mine	51	1212420	1678620	27	51-27-51	4x
non-mine	52	1224450	1678380	27	51-27-52	4x
non-mine	53	1236480	1678170	27	51-27-53	4x
non-mine	55	1227030	1677840	27	51-27-55	4x
non-mine	56	1205520	1677750	27	51-27-56	4x
non-mine	59	1208100	1677210	27	51-27-59	4x
non-mine	60	1220130	1676970	27	51-27-60	4x
non-mine	61	1232160	1676730	27	51-27-61	4x
non-mine	62	1210680	1676640	27	51-27-62	4x
non-mine	63	1222710	1676430	27	51-27-63	4x
non-mine	64	1234740	1676190	27	51-27-64	4x
non-mine	66	1225290	1675860	27	51-27-66	4x
non-mine	67	1203810	1675770	27	51-27-67	4x

non-mine	68	1237320	1675650	27	51-27-68	4x
non-mine	69	1215840	1675560	27	51-27-69	4x
non-mine	70	1227870	1675320	27	51-27-70	4x
non-mine	71	1206390	1675230	27	51-27-71	4x
non-mine	72	1218420	1674990	27	51-27-72	4x
non-mine	73	1230450	1674780	27	51-27-73	4x
non-mine	74	1208940	1674690	27	51-27-74	4x
non-mine	75	1242480	1674540	27	51-27-75	4x
non-mine	76	1220970	1674450	27	51-27-76	4x
non-mine	77	1233000	1674240	27	51-27-77	4x
non-mine	78	1211520	1674150	27	51-27-78	4x
non-mine	79	1245030	1674000	27	51-27-79	4x
non-mine	80	1223550	1673910	27	51-27-80	4x
non-mine	82	1235580	1673670	27	51-27-82	4x
non-mine	83	1214100	1673580	27	51-27-83	4x
non-mine	84	1247610	1673460	27	51-27-84	4x
non-mine	85	1226130	1673370	27	51-27-85	4x
non-mine	86	1204650	1673280	27	51-27-86	4x
non-mine	87	1238160	1673130	27	51-27-87	4x
non-mine	88	1216680	1673040	27	51-27-88	4x
non-mine	89	1228710	1672800	27	51-27-89	4x
non-mine	90	1207230	1672710	27	51-27-90	4x
non-mine	91	1240740	1672590	27	51-27-91	4x
non-mine	92	1219260	1672500	27	51-27-92	4x
non-mine	93	1231290	1672260	27	51-27-93	4x
non-mine	94	1209810	1672170	27	51-27-94	4x
non-mine	95	1243320	1672050	27	51-27-95	4x
non-mine	96	1221810	1671930	27	51-27-96	4x
non-mine	97	1200330	1671840	27	51-27-97	4x
non-mine	98	1233840	1671720	27	51-27-98	4x
non-mine	99	1212360	1671630	27	51-27-99	4x
non-mine	100	1245900	1671480	27	51-27-100	4x
non-mine	101	1224390	1671390	27	51-27-101	4x
non-mine	102	1202910	1671300	27	51-27-102	4x
non-mine	103	1236420	1671180	27	51-27-103	4x
non-mine	104	1214940	1671090	27	51-27-104	4x
non-mine	105	1226970	1670850	27	51-27-105	4x
non-mine	106	1205490	1670760	27	51-27-106	4x

non-mine	107	1239000	1670610	27	51-27-107	4x
non-mine	108	1217520	1670520	27	51-27-108	4x
non-mine	109	1229550	1670310	27	51-27-109	4x
non-mine	110	1208070	1670220	27	51-27-110	4x
non-mine	111	1241580	1670070	27	51-27-111	4x
non-mine	112	1220100	1669980	27	51-27-112	4x
non-mine	115	1210650	1669650	27	51-27-115	4x
non-mine	116	1244160	1669530	27	51-27-116	4x
non-mine	119	1234710	1669200	27	51-27-119	4x
non-mine	121	1246740	1668960	27	51-27-121	4x
non-mine	122	1225230	1668870	27	51-27-122	4x
non-mine	124	1237260	1668660	27	51-27-124	4x
non-mine	125	1215780	1668570	27	51-27-125	4x
non-mine	126	1227810	1668330	27	51-27-126	4x
non-mine	127	1206330	1668240	27	51-27-127	4x
non-mine	128	1239840	1668120	27	51-27-128	4x
non-mine	129	1218360	1668000	27	51-27-129	4x
non-mine	131	1230390	1667790	27	51-27-131	4x
non-mine	133	1242420	1667550	27	51-27-133	4x
non-mine	134	1220940	1667460	27	51-27-134	4x
non-mine	136	1232970	1667250	27	51-27-136	4x
non-mine	137	1211490	1667130	27	51-27-137	4x
non-mine	138	1245000	1667010	27	51-27-138	4x
non-mine	141	1235550	1666680	27	51-27-141	4x
non-mine	142	1214070	1666590	27	51-27-142	4x
non-mine	143	1226100	1666380	27	51-27-143	4x
non-mine	144	1204590	1666260	27	51-27-144	4x
non-mine	145	1238130	1666140	27	51-27-145	4x
non-mine	148	1228650	1665810	27	51-27-148	4x
non-mine	149	1207170	1665720	27	51-27-149	4x
non-mine	150	1240680	1665600	27	51-27-150	4x
non-mine	151	1219200	1665510	27	51-27-151	4x
non-mine	153	1231230	1665270	27	51-27-153	4x
non-mine	154	1209750	1665180	27	51-27-154	4x
non-mine	155	1243260	1665060	27	51-27-155	4x
non-mine	156	1221780	1664940	27	51-27-156	4x
non-mine	158	1233810	1664730	27	51-27-158	4x
non-mine	163	1236390	1664190	27	51-27-163	4x

non-mine	164	1214910	1664070	27	51-27-164	4x
non-mine	166	1226940	1663860	27	51-27-166	4x
non-mine	167	1205460	1663770	27	51-27-167	4x
non-mine	168	1238970	1663620	27	51-27-168	4x
non-mine	169	1217490	1663530	27	51-27-169	4x
non-mine	171	1229520	1663320	27	51-27-171	4x
non-mine	173	1220040	1662990	27	51-27-173	4x
non-mine	175	1232070	1662750	27	51-27-175	4x
non-mine	176	1210590	1662660	27	51-27-176	4x
non-mine	178	1222620	1662450	27	51-27-178	4x
non-mine	180	1234650	1662210	27	51-27-180	4x
non-mine	185	1237230	1661670	27	51-27-185	4x
non-mine	186	1215750	1661580	27	51-27-186	4x
non-mine	188	1227780	1661340	27	51-27-188	4x
non-mine	189	1206300	1661250	27	51-27-189	4x
non-mine	191	1218330	1661010	27	51-27-191	4x
non-mine	193	1230360	1660800	27	51-27-193	4x
non-mine	196	1220880	1660470	27	51-27-196	4x
non-mine	198	1232910	1660260	27	51-27-198	4x
non-mine	199	1211430	1660140	27	51-27-199	4x
non-mine	201	1223460	1659930	27	51-27-201	4x
non-mine	203	1235490	1659690	27	51-27-203	4x
non-mine	204	1214010	1659600	27	51-27-204	4x
non-mine	206	1226040	1659390	27	51-27-206	4x
non-mine	209	1216590	1659060	27	51-27-209	4x
non-mine	211	1228620	1658820	27	51-27-211	4x
non-mine	214	1219170	1658520	27	51-27-214	4x
non-mine	216	1231200	1658280	27	51-27-216	4x
non-mine	217	1209720	1658190	27	51-27-217	4x
non-mine	219	1221750	1657950	27	51-27-219	4x
non-mine	221	1233780	1657740	27	51-27-221	4x
non-mine	222	1212270	1657650	27	51-27-222	4x
non-mine	224	1224300	1657410	27	51-27-224	4x
non-mine	228	1214850	1657080	27	51-27-228	4x
non-mine	230	1226880	1656870	27	51-27-230	4x
non-mine	233	1217430	1656540	27	51-27-233	4x
non-mine	235	1229460	1656330	27	51-27-235	4x
non-mine	238	1220010	1656000	27	51-27-238	4x

non-mine	244	1222590	1655460	27	51-27-244	4x
non-mine	248	1213140	1655130	27	51-27-248	4x
non-mine	250	1225170	1654890	27	51-27-250	4x
non-mine	259	1218270	1654020	27	51-27-259	4x
non-mine	265	1220850	1653480	27	51-27-265	4x
non-mine	271	1223430	1652940	27	51-27-271	4x
non-mine	275	1213980	1652610	27	51-27-275	4x
non-mine	277	1226010	1652400	27	51-27-277	4x
non-mine	281	1216560	1652070	27	51-27-281	4x
non-mine	288	1219110	1651530	27	51-27-288	4x
non-mine	294	1221690	1650960	27	51-27-294	4x
non-mine	300	1224270	1650420	27	51-27-300	4x
non-mine	304	1214820	1650090	27	51-27-304	4x
non-mine	307	1226850	1649880	27	51-27-307	4x
non-mine	325	1222530	1648470	27	51-27-325	4x
non-mine	332	1225110	1647900	27	51-27-332	4x
non-mine	343	1218240	1647030	27	51-27-343	4x
non-mine	350	1220820	1646490	27	51-27-350	4x
non-mine	376	1219080	1644540	27	51-27-376	4x
non-mine	113	1198620	1669890	51	51-51-113	4x
non-mine	118	1201200	1669350	51	51-51-118	4x
non-mine	130	1196880	1667910	51	51-51-130	4x
non-mine	135	1199460	1667370	51	51-51-135	4x
non-mine	140	1202040	1666830	51	51-51-140	4x
non-mine	147	1195140	1665960	51	51-51-147	4x
non-mine	152	1197720	1665390	51	51-51-152	4x
non-mine	157	1200300	1664850	51	51-51-157	4x
non-mine	160	1190850	1664520	51	51-51-160	4x
non-mine	162	1202880	1664310	51	51-51-162	4x
non-mine	165	1193430	1663980	51	51-51-165	4x
non-mine	170	1195980	1663440	51	51-51-170	4x
non-mine	174	1198560	1662900	51	51-51-174	4x
non-mine	177	1189110	1662570	51	51-51-177	4x
non-mine	179	1201140	1662330	51	51-51-179	4x
non-mine	182	1191690	1662030	51	51-51-182	4x
non-mine	184	1203720	1661790	51	51-51-184	4x
non-mine	187	1194270	1661460	51	51-51-187	4x
non-mine	190	1184820	1661160	51	51-51-190	4x

non-mine	192	1196850	1660920	51	51-51-192	4x
non-mine	195	1187400	1660590	51	51-51-195	4x
non-mine	197	1199400	1660380	51	51-51-197	4x
non-mine	200	1189950	1660050	51	51-51-200	4x
non-mine	202	1201980	1659840	51	51-51-202	4x
non-mine	205	1192530	1659510	51	51-51-205	4x
non-mine	207	1204560	1659270	51	51-51-207	4x
non-mine	208	1183080	1659180	51	51-51-208	4x
non-mine	210	1195110	1658970	51	51-51-210	4x
non-mine	212	1207140	1658730	51	51-51-212	4x
non-mine	213	1185660	1658640	51	51-51-213	4x
non-mine	215	1197690	1658400	51	51-51-215	4x
non-mine	218	1188240	1658100	51	51-51-218	4x
non-mine	220	1200270	1657860	51	51-51-220	4x
non-mine	223	1190790	1657530	51	51-51-223	4x
non-mine	225	1202820	1657320	51	51-51-225	4x
non-mine	226	1181340	1657200	51	51-51-226	4x
non-mine	229	1193370	1656990	51	51-51-229	4x
non-mine	231	1205400	1656780	51	51-51-231	4x
non-mine	232	1183920	1656660	51	51-51-232	4x
non-mine	236	1207980	1656210	51	51-51-236	4x
non-mine	239	1198530	1655910	51	51-51-239	4x
non-mine	242	1210560	1655670	51	51-51-242	4x
non-mine	246	1179630	1655250	51	51-51-246	4x
non-mine	249	1191660	1655040	51	51-51-249	4x
non-mine	251	1203690	1654800	51	51-51-251	4x
non-mine	255	1194210	1654470	51	51-51-255	4x
non-mine	257	1206240	1654260	51	51-51-257	4x
non-mine	258	1184760	1654140	51	51-51-258	4x
non-mine	263	1208820	1653720	51	51-51-263	4x
non-mine	264	1187340	1653600	51	51-51-264	4x
non-mine	266	1199370	1653390	51	51-51-266	4x
non-mine	269	1211400	1653150	51	51-51-269	4x
non-mine	270	1189920	1653060	51	51-51-270	4x
non-mine	273	1180470	1652730	51	51-51-273	4x
non-mine	276	1192500	1652520	51	51-51-276	4x
non-mine	282	1195080	1651980	51	51-51-282	4x
non-mine	285	1207080	1651740	51	51-51-285	4x

non-mine	289	1197630	1651410	51	51-51-289	4x
non-mine	292	1209660	1651200	51	51-51-292	4x
non-mine	295	1200210	1650870	51	51-51-295	4x
non-mine	298	1212240	1650660	51	51-51-298	4x
non-mine	299	1190760	1650540	51	51-51-299	4x
non-mine	301	1202790	1650330	51	51-51-301	4x
non-mine	302	1181310	1650210	51	51-51-302	4x
non-mine	305	1193340	1650000	51	51-51-305	4x
non-mine	308	1205370	1649790	51	51-51-308	4x
non-mine	309	1183890	1649670	51	51-51-309	4x
non-mine	312	1195920	1649460	51	51-51-312	4x
non-mine	315	1207950	1649220	51	51-51-315	4x
non-mine	316	1186470	1649130	51	51-51-316	4x
non-mine	319	1198500	1648920	51	51-51-319	4x
non-mine	322	1210500	1648680	51	51-51-322	4x
non-mine	323	1189020	1648590	51	51-51-323	4x
non-mine	326	1201050	1648350	51	51-51-326	4x
non-mine	330	1191600	1648020	51	51-51-330	4x
non-mine	341	1184730	1647150	51	51-51-341	4x
non-mine	344	1196760	1646940	51	51-51-344	4x
non-mine	348	1187310	1646610	51	51-51-348	4x
non-mine	351	1199340	1646400	51	51-51-351	4x
non-mine	354	1211370	1646160	51	51-51-354	4x
non-mine	363	1192440	1645530	51	51-51-363	4x
non-mine	366	1204470	1645290	51	51-51-366	4x
non-mine	370	1195020	1644960	51	51-51-370	4x
non-mine	373	1207050	1644750	51	51-51-373	4x
non-mine	377	1197600	1644420	51	51-51-377	4x
non-mine	380	1209630	1644210	51	51-51-380	4x
non-mine	381	1188150	1644090	51	51-51-381	4x
non-mine	388	1212210	1643670	51	51-51-388	4x
non-mine	389	1190730	1643550	51	51-51-389	4x
non-mine	397	1193310	1643010	51	51-51-397	4x
non-mine	400	1205310	1642800	51	51-51-400	4x
non-mine	404	1195860	1642470	51	51-51-404	4x
non-mine	407	1207890	1642230	51	51-51-407	4x
non-mine	408	1186410	1642140	51	51-51-408	4x
non-mine	411	1198440	1641900	51	51-51-411	4x

non-mine	414	1210470	1641690	51	51-51-414	4x
non-mine	419	1201020	1641360	51	51-51-419	4x
non-mine	423	1191570	1641030	51	51-51-423	4x
non-mine	431	1194150	1640490	51	51-51-431	4x
non-mine	451	1189830	1639080	51	51-51-451	4x
non-mine	455	1201860	1638870	51	51-51-455	4x
non-mine	459	1192410	1638540	51	51-51-459	4x
non-mine	462	1204440	1638300	51	51-51-462	4x
non-mine	473	1197570	1637430	51	51-51-473	4x
non-mine	481	1200150	1636890	51	51-51-481	4x
non-mine	489	1202700	1636350	51	51-51-489	4x
non-mine	500	1195830	1635480	51	51-51-500	4x
non-mine	516	1200990	1634370	51	51-51-516	4x
non-mine	283	1173600	1651860	195	51-195-283	4x
non-mine	290	1176150	1651320	195	51-195-290	4x
non-mine	296	1178730	1650780	195	51-195-296	4x
non-mine	306	1171860	1649880	195	51-195-306	4x
non-mine	313	1174440	1649340	195	51-195-313	4x
non-mine	320	1177020	1648800	195	51-195-320	4x
non-mine	331	1170120	1647930	195	51-195-331	4x
non-mine	338	1172700	1647390	195	51-195-338	4x
non-mine	357	1168410	1645950	195	51-195-357	4x
non-mine	360	1180440	1645740	195	51-195-360	4x
non-mine	364	1170990	1645410	195	51-195-364	4x
non-mine	378	1176120	1644330	195	51-195-378	4x
non-mine	391	1169250	1643460	195	51-195-391	4x
non-mine	398	1171830	1642890	195	51-195-398	4x
non-mine	401	1183860	1642680	195	51-195-401	4x
non-mine	405	1174410	1642350	195	51-195-405	4x
non-mine	417	1167510	1641480	195	51-195-417	4x
non-mine	425	1170090	1640940	195	51-195-425	4x
non-mine	440	1175250	1639830	195	51-195-440	4x
non-mine	448	1177800	1639290	195	51-195-448	4x
non-mine	463	1182960	1638210	195	51-195-463	4x
non-mine	467	1173510	1637880	195	51-195-467	4x
non-mine	470	1185540	1637670	195	51-195-470	4x
non-mine	474	1176090	1637340	195	51-195-474	4x
non-mine	477	1188120	1637100	195	51-195-477	4x

non-mine	485	1190700	1636560	195	51-195-485	4x
non-mine	512	1188960	1634610	195	51-195-512	4x
non-mine	517	1179510	1634280	195	51-195-517	4x
non-mine	520	1191540	1634040	195	51-195-520	4x
non-mine	531	1184640	1633170	195	51-195-531	4x
non-mine	535	1196670	1632960	195	51-195-535	4x
non-mine	536	1175190	1632840	195	51-195-536	4x
non-mine	544	1177770	1632300	195	51-195-544	4x
non-mine	550	1201830	1631850	195	51-195-550	4x
non-mine	551	1180350	1631760	195	51-195-551	4x
non-mine	555	1192380	1631550	195	51-195-555	4x
non-mine	556	1170900	1631430	195	51-195-556	4x
non-mine	559	1182930	1631220	195	51-195-559	4x
non-mine	563	1194960	1630980	195	51-195-563	4x
non-mine	564	1173480	1630890	195	51-195-564	4x
non-mine	567	1185510	1630650	195	51-195-567	4x
non-mine	572	1176060	1630320	195	51-195-572	4x
non-mine	575	1188060	1630110	195	51-195-575	4x
non-mine	579	1178610	1629780	195	51-195-579	4x
non-mine	583	1190640	1629570	195	51-195-583	4x
non-mine	586	1202670	1629360	195	51-195-586	4x
non-mine	591	1193220	1629030	195	51-195-591	4x
non-mine	595	1183770	1628700	195	51-195-595	4x
non-mine	596	1162290	1628580	195	51-195-596	4x
non-mine	599	1174320	1628370	195	51-195-599	4x
non-mine	602	1186350	1628160	195	51-195-602	4x
non-mine	603	1164870	1628040	195	51-195-603	4x
non-mine	605	1198380	1627920	195	51-195-605	4x
non-mine	610	1188930	1627590	195	51-195-610	4x
non-mine	613	1200960	1627380	195	51-195-613	4x
non-mine	614	1179480	1627260	195	51-195-614	4x
non-mine	618	1170030	1626930	195	51-195-618	4x
non-mine	621	1182030	1626720	195	51-195-621	4x
non-mine	624	1194060	1626510	195	51-195-624	4x
non-mine	625	1172580	1626390	195	51-195-625	4x
non-mine	628	1184610	1626180	195	51-195-628	4x
non-mine	634	1187190	1625640	195	51-195-634	4x
non-mine	641	1189770	1625100	195	51-195-641	4x

non-mine	642	1168290	1624980	195	51-195-642	4x
non-mine	645	1180320	1624770	195	51-195-645	4x
non-mine	646	1158840	1624650	195	51-195-646	4x
non-mine	648	1192350	1624530	195	51-195-648	4x
non-mine	651	1182900	1624230	195	51-195-651	4x
non-mine	654	1194900	1623990	195	51-195-654	4x
non-mine	655	1173450	1623900	195	51-195-655	4x
non-mine	657	1185450	1623660	195	51-195-657	4x
non-mine	660	1197480	1623450	195	51-195-660	4x
non-mine	663	1188030	1623120	195	51-195-663	4x
non-mine	667	1178580	1622790	195	51-195-667	4x
non-mine	670	1169130	1622460	195	51-195-670	4x
non-mine	672	1181160	1622250	195	51-195-672	4x
non-mine	673	1159680	1622130	195	51-195-673	4x
non-mine	675	1171710	1621920	195	51-195-675	4x
non-mine	677	1183740	1621710	195	51-195-677	4x
non-mine	680	1174290	1621380	195	51-195-680	4x
non-mine	682	1164840	1621050	195	51-195-682	4x
non-mine	685	1155390	1620720	195	51-195-685	4x
non-mine	687	1167420	1620510	195	51-195-687	4x
non-mine	692	1169970	1619940	195	51-195-692	4x
non-mine	696	1172550	1619400	195	51-195-696	4x
non-mine	698	1163100	1619070	195	51-195-698	4x
non-mine	700	1175130	1618860	195	51-195-700	4x
non-mine	702	1165680	1618530	195	51-195-702	4x
non-mine	707	1168260	1617990	195	51-195-707	4x
non-mine	710	1158810	1617660	195	51-195-710	4x
non-mine	712	1170840	1617450	195	51-195-712	4x
non-mine	714	1161390	1617120	195	51-195-714	4x
non-mine	716	1173390	1616880	195	51-195-716	4x
non-mine	719	1163940	1616550	195	51-195-719	4x
non-mine	721	1166520	1616010	195	51-195-721	4x
non-mine	723	1169100	1615470	195	51-195-723	4x
non-mine	725	1159650	1615140	195	51-195-725	4x
non-mine	727	1171680	1614930	195	51-195-727	4x
non-mine	729	1162230	1614600	195	51-195-729	4x
non-mine	732	1164810	1614060	195	51-195-732	4x
non-mine	734	1167360	1613490	195	51-195-734	4x

non-mine	736	1169940	1612950	195	51-195-736	4x
non-mine	741	1165650	1611540	195	51-195-741	4x
non-mine	227	1236330	1657200	167	51-167-227	4x
non-mine	241	1232040	1655760	167	51-167-241	4x
non-mine	247	1234620	1655220	167	51-167-247	4x
non-mine	253	1237200	1654680	167	51-167-253	4x
non-mine	256	1227720	1654350	167	51-167-256	4x
non-mine	262	1230300	1653810	167	51-167-262	4x
non-mine	268	1232880	1653270	167	51-167-268	4x
non-mine	274	1235460	1652700	167	51-167-274	4x
non-mine	280	1238040	1652160	167	51-167-280	4x
non-mine	284	1228590	1651830	167	51-167-284	4x
non-mine	287	1240620	1651620	167	51-167-287	4x
non-mine	310	1238880	1649640	167	51-167-310	4x
non-mine	314	1229430	1649340	167	51-167-314	4x
non-mine	317	1241460	1649100	167	51-167-317	4x
non-mine	321	1232010	1648770	167	51-167-321	4x
non-mine	324	1244040	1648560	167	51-167-324	4x
non-mine	328	1234560	1648230	167	51-167-328	4x
non-mine	335	1237140	1647690	167	51-167-335	4x
non-mine	339	1227690	1647360	167	51-167-339	4x
non-mine	342	1239720	1647150	167	51-167-342	4x
non-mine	346	1230270	1646820	167	51-167-346	4x
non-mine	349	1242300	1646580	167	51-167-349	4x
non-mine	353	1232850	1646280	167	51-167-353	4x
non-mine	356	1244880	1646040	167	51-167-356	4x
non-mine	365	1225950	1645410	167	51-167-365	4x
non-mine	368	1237980	1645170	167	51-167-368	4x
non-mine	372	1228530	1644840	167	51-167-372	4x
non-mine	375	1240560	1644630	167	51-167-375	4x
non-mine	379	1231110	1644300	167	51-167-379	4x
non-mine	382	1243140	1644090	167	51-167-382	4x
non-mine	384	1221660	1643970	167	51-167-384	4x
non-mine	387	1233690	1643760	167	51-167-387	4x
non-mine	390	1245720	1643520	167	51-167-390	4x
non-mine	392	1224240	1643430	167	51-167-392	4x
non-mine	395	1236270	1643220	167	51-167-395	4x
non-mine	396	1214790	1643100	167	51-167-396	4x

non-mine	399	1226820	1642890	167	51-167-399	4x
non-mine	402	1238850	1642650	167	51-167-402	4x
non-mine	406	1229370	1642350	167	51-167-406	4x
non-mine	409	1241400	1642110	167	51-167-409	4x
non-mine	410	1219920	1642020	167	51-167-410	4x
non-mine	413	1231950	1641780	167	51-167-413	4x
non-mine	416	1243980	1641570	167	51-167-416	4x
non-mine	421	1234530	1641240	167	51-167-421	4x
non-mine	422	1213050	1641150	167	51-167-422	4x
non-mine	424	1246560	1641030	167	51-167-424	4x
non-mine	426	1225080	1640910	167	51-167-426	4x
non-mine	429	1237110	1640700	167	51-167-429	4x
non-mine	430	1215630	1640610	167	51-167-430	4x
non-mine	432	1249140	1640460	167	51-167-432	4x
non-mine	434	1227660	1640370	167	51-167-434	4x
non-mine	437	1239690	1640160	167	51-167-437	4x
non-mine	438	1218210	1640040	167	51-167-438	4x
non-mine	441	1230240	1639830	167	51-167-441	4x
non-mine	444	1242270	1639590	167	51-167-444	4x
non-mine	446	1220760	1639500	167	51-167-446	4x
non-mine	449	1232790	1639290	167	51-167-449	4x
non-mine	452	1244820	1639050	167	51-167-452	4x
non-mine	454	1223340	1638960	167	51-167-454	4x
non-mine	457	1235370	1638720	167	51-167-457	4x
non-mine	461	1225920	1638420	167	51-167-461	4x
non-mine	465	1216470	1638090	167	51-167-465	4x
non-mine	468	1228500	1637850	167	51-167-468	4x
non-mine	471	1240530	1637640	167	51-167-471	4x
non-mine	475	1231080	1637310	167	51-167-475	4x
non-mine	478	1243110	1637100	167	51-167-478	4x
non-mine	480	1221630	1636980	167	51-167-480	4x
non-mine	483	1233660	1636770	167	51-167-483	4x
non-mine	484	1212150	1636680	167	51-167-484	4x
non-mine	486	1245690	1636530	167	51-167-486	4x
non-mine	488	1224180	1636440	167	51-167-488	4x
non-mine	491	1236210	1636230	167	51-167-491	4x
non-mine	492	1214730	1636110	167	51-167-492	4x
non-mine	495	1226760	1635900	167	51-167-495	4x

non-mine	496	1205280	1635810	167	51-167-496	4x
non-mine	498	1238790	1635660	167	51-167-498	4x
non-mine	499	1217310	1635570	167	51-167-499	4x
non-mine	502	1229340	1635360	167	51-167-502	4x
non-mine	503	1207860	1635240	167	51-167-503	4x
non-mine	505	1241370	1635120	167	51-167-505	4x
non-mine	507	1219890	1635030	167	51-167-507	4x
non-mine	510	1231920	1634790	167	51-167-510	4x
non-mine	513	1243950	1634580	167	51-167-513	4x
non-mine	515	1222470	1634490	167	51-167-515	4x
non-mine	518	1234500	1634250	167	51-167-518	4x
non-mine	522	1225050	1633920	167	51-167-522	4x
non-mine	525	1237080	1633710	167	51-167-525	4x
non-mine	526	1215600	1633620	167	51-167-526	4x
non-mine	529	1227600	1633380	167	51-167-529	4x
non-mine	530	1206120	1633290	167	51-167-530	4x
non-mine	532	1239660	1633170	167	51-167-532	4x
non-mine	534	1218150	1633050	167	51-167-534	4x
non-mine	537	1230180	1632840	167	51-167-537	4x
non-mine	538	1208700	1632750	167	51-167-538	4x
non-mine	540	1242210	1632600	167	51-167-540	4x
non-mine	542	1220730	1632510	167	51-167-542	4x
non-mine	545	1232760	1632300	167	51-167-545	4x
non-mine	546	1211280	1632180	167	51-167-546	4x
non-mine	549	1223310	1631970	167	51-167-549	4x
non-mine	554	1213860	1631640	167	51-167-554	4x
non-mine	557	1225890	1631430	167	51-167-557	4x
non-mine	558	1204410	1631310	167	51-167-558	4x
non-mine	560	1237920	1631190	167	51-167-560	4x
non-mine	562	1216440	1631100	167	51-167-562	4x
non-mine	565	1228470	1630860	167	51-167-565	4x
non-mine	566	1206990	1630770	167	51-167-566	4x
non-mine	568	1240500	1630650	167	51-167-568	4x
non-mine	570	1219020	1630560	167	51-167-570	4x
non-mine	573	1231050	1630320	167	51-167-573	4x
non-mine	577	1221570	1629990	167	51-167-577	4x
non-mine	580	1233600	1629780	167	51-167-580	4x
non-mine	581	1212120	1629690	167	51-167-581	4x

non-mine	585	1224150	1629450	167	51-167-585	4x
non-mine	588	1236180	1629240	167	51-167-588	4x
non-mine	590	1214700	1629120	167	51-167-590	4x
non-mine	593	1226730	1628910	167	51-167-593	4x
non-mine	594	1205250	1628790	167	51-167-594	4x
non-mine	597	1217280	1628580	167	51-167-597	4x
non-mine	600	1229310	1628370	167	51-167-600	4x
non-mine	601	1207830	1628250	167	51-167-601	4x
non-mine	604	1219860	1628040	167	51-167-604	4x
non-mine	607	1231890	1627800	167	51-167-607	4x
non-mine	609	1210410	1627710	167	51-167-609	4x
non-mine	612	1222440	1627500	167	51-167-612	4x
non-mine	616	1212960	1627170	167	51-167-616	4x
non-mine	619	1224990	1626930	167	51-167-619	4x
non-mine	620	1203510	1626840	167	51-167-620	4x
non-mine	622	1215540	1626630	167	51-167-622	4x
non-mine	626	1227570	1626390	167	51-167-626	4x
non-mine	627	1206090	1626300	167	51-167-627	4x
non-mine	630	1218120	1626060	167	51-167-630	4x
non-mine	633	1208670	1625730	167	51-167-633	4x
non-mine	636	1220700	1625520	167	51-167-636	4x
non-mine	640	1211250	1625190	167	51-167-640	4x
non-mine	643	1223280	1624980	167	51-167-643	4x
non-mine	644	1201800	1624860	167	51-167-644	4x
non-mine	647	1213830	1624650	167	51-167-647	4x
non-mine	650	1204380	1624320	167	51-167-650	4x
non-mine	653	1216380	1624110	167	51-167-653	4x
non-mine	656	1206930	1623780	167	51-167-656	4x
non-mine	659	1218960	1623570	167	51-167-659	4x
non-mine	662	1209510	1623240	167	51-167-662	4x
non-mine	665	1221540	1623000	167	51-167-665	4x
non-mine	666	1200060	1622910	167	51-167-666	4x
non-mine	668	1212090	1622700	167	51-167-668	4x
non-mine	671	1202640	1622370	167	51-167-671	4x
non-mine	676	1205220	1621800	167	51-167-676	4x
non-mine	679	1217250	1621590	167	51-167-679	4x
non-mine	681	1207800	1621260	167	51-167-681	4x
non-mine	683	1219830	1621050	167	51-167-683	4x

non-mine	684	1198320	1620930	167	51-167-684	4x
non-mine	686	1210350	1620720	167	51-167-686	4x
non-mine	688	1222380	1620510	167	51-167-688	4x
non-mine	689	1200900	1620390	167	51-167-689	4x
non-mine	691	1212930	1620180	167	51-167-691	4x
non-mine	693	1203480	1619850	167	51-167-693	4x
non-mine	694	1215510	1619640	167	51-167-694	4x
non-mine	697	1206060	1619310	167	51-167-697	4x
non-mine	699	1218090	1619070	167	51-167-699	4x
non-mine	701	1208640	1618740	167	51-167-701	4x
non-mine	703	1220670	1618530	167	51-167-703	4x
non-mine	704	1199190	1618440	167	51-167-704	4x
non-mine	706	1211220	1618200	167	51-167-706	4x
non-mine	708	1223250	1617990	167	51-167-708	4x
non-mine	709	1201770	1617870	167	51-167-709	4x
non-mine	711	1213770	1617660	167	51-167-711	4x
non-mine	713	1204320	1617330	167	51-167-713	4x
non-mine	715	1216350	1617120	167	51-167-715	4x
non-mine	717	1206900	1616790	167	51-167-717	4x
non-mine	718	1218930	1616580	167	51-167-718	4x
non-mine	720	1209480	1616250	167	51-167-720	4x
non-mine	722	1212060	1615680	167	51-167-722	4x
non-mine	724	1202610	1615380	167	51-167-724	4x
non-mine	726	1214640	1615140	167	51-167-726	4x
non-mine	728	1205190	1614810	167	51-167-728	4x
non-mine	730	1217220	1614600	167	51-167-730	4x
non-mine	731	1207740	1614270	167	51-167-731	4x
non-mine	733	1210320	1613730	167	51-167-733	4x
non-mine	735	1212900	1613190	167	51-167-735	4x
non-mine	737	1203450	1612860	167	51-167-737	4x
non-mine	738	1206030	1612320	167	51-167-738	4x
non-mine	740	1208610	1611750	167	51-167-740	4x
non-mine	742	1211160	1611210	167	51-167-742	4x
non-mine	743	1204290	1610340	167	51-167-743	4x
non-mine	744	1206870	1609800	167	51-167-744	4x
non-mine	745	1209450	1609260	167	51-167-745	4x
non-mine	746	1205130	1607820	167	51-167-746	4x

Appendix E: Sample points in "Mined" category used to develop model (Chapter 5)

PROJID shows the unique identifier of photo-plot as Federal Information Processing Standards (FIPS) codes for State-County_PointID*; Ref. canopy is the Reference data developed by photo-interpretation. 2008 and 2009 represent leaf-on and leaf-off Landsat scenes respectively. Fcm and fst denote focal mean and focal standard deviation respectively. "b" represents Landsat band and "tc" represents Tasseled cap.

PROJID	Ref. canopy	2009 b4fcm	2009 b1_fst	2008 tc1_fcm	2008 ndvi_fcm	2008 ndvi_fst	2009 ndvi_fcm	Cos fcm	Sin fcm	Slope fcm
51-27-4	0.000	1316.889	80.156	4928.508	0.175	0.033	0.103	-0.645	-0.633	24.126
51-27-7	0.000	1740.667	96.681	4207.589	0.515	0.103	0.292	0.919	-0.394	15.866
51-27-15	0.876	336.889	48.500	1883.154	0.824	0.015	0.314	0.771	-0.583	167.773
51-27-25	0.743	1693.556	79.047	3124.538	0.845	0.011	0.374	-0.864	0.034	149.924
51-27-33	0.800	2207.556	37.537	3124.423	0.842	0.015	0.530	-0.480	0.873	91.336
51-27-48	0.657	1462.556	78.298	2816.674	0.848	0.008	0.377	-0.228	0.355	139.769
51-27-49	0.762	1660.667	88.534	3023.666	0.876	0.011	0.365	-0.584	-0.406	126.302
51-27-58	0.000	1237.778	67.041	4243.374	0.179	0.010	0.103	-0.947	0.220	104.407
51-27-65	0.848	1442.778	46.926	2909.642	0.854	0.007	0.357	-0.809	-0.565	158.079
51-27-114	0.152	1152.000	37.801	2792.550	0.635	0.072	0.238	0.675	0.355	10.013
51-27-139	0.476	846.556	51.443	2553.198	0.740	0.031	0.203	0.337	-0.855	99.893
51-27-159	0.000	2294.000	58.313	3381.938	0.495	0.038	0.265	-0.944	0.280	134.013
51-27-161	0.867	807.222	54.127	2416.576	0.851	0.007	0.376	-0.428	-0.863	187.399
51-27-172	0.829	1987.889	58.749	2819.262	0.827	0.014	0.682	0.600	0.318	75.505
51-27-183	0.552	1363.333	51.332	2746.815	0.797	0.024	0.332	-0.692	-0.707	191.775

51-27-194	0.686	1904.778	72.629	3367.797	0.779	0.039	0.339	-0.887	-0.298	107.588
51-27-254	0.790	1350.889	93.771	3196.873	0.847	0.027	0.470	-0.404	-0.850	99.443
51-27-358	0.029	566.000	23.726	2717.793	0.683	0.082	0.258	0.269	-0.931	136.096
51-51-234	0.067	2016.778	56.294	3290.740	0.677	0.024	0.302	-0.436	0.665	95.109
51-51-245	0.781	2016.444	45.697	3221.315	0.833	0.012	0.455	-0.545	0.696	93.515
51-51-278	0.752	549.222	46.897	2751.886	0.846	0.010	0.319	0.969	0.102	147.794
51-51-279	0.419	2031.222	105.393	3317.507	0.775	0.048	0.516	-0.011	0.925	120.852
51-51-286	0.638	1218.111	45.652	2717.962	0.810	0.024	0.398	0.629	-0.666	72.524
51-51-340	0.029	1931.000	26.667	3259.868	0.705	0.023	0.345	-0.527	0.831	138.436
51-51-435	0.029	860.667	36.517	2974.809	0.628	0.095	0.247	0.525	-0.826	94.411
51-51-508	0.705	2240.444	96.362	4150.198	0.689	0.121	0.295	-0.117	0.970	201.487
51-167-418	0.000	2384.444	59.115	4127.401	0.648	0.042	0.324	0.076	0.943	130.634
51-167-450	0.305	2444.778	57.769	3290.088	0.802	0.017	0.417	0.139	0.369	134.036
51-167-464	0.162	1450.667	45.763	3017.941	0.703	0.019	0.302	0.010	-0.986	108.854
51-167-523	0.590	1152.000	77.429	3026.256	0.791	0.055	0.373	0.225	-0.787	58.961
51-167-552	0.933	1603.556	86.821	3433.177	0.735	0.036	0.384	0.463	0.331	66.253
51-167-574	0.695	1458.667	46.781	2427.855	0.712	0.023	0.482	0.296	0.605	84.759
51-167-674	0.267	2109.000	58.355	3471.824	0.652	0.040	0.348	0.201	0.707	33.827
51-195-367	0.000	1495.778	48.445	2939.316	0.591	0.025	0.299	-0.025	0.162	60.104
51-195-383	0.914	1944.333	28.014	3715.475	0.865	0.011	0.425	-0.825	0.500	83.601
51-195-394	0.276	1423.889	73.247	2896.055	0.771	0.057	0.296	0.831	-0.301	69.490
51-195-412	0.048	1635.222	61.074	3122.761	0.728	0.041	0.327	0.941	-0.243	83.576
51-195-420	0.743	2101.667	23.786	3992.391	0.854	0.012	0.396	-0.649	0.714	134.043
51-195-445	0.152	983.333	43.787	2768.500	0.724	0.015	0.293	0.975	-0.217	79.269
51-195-453	0.133	673.333	30.635	2551.308	0.691	0.121	0.254	0.030	-0.977	160.307
51-195-456	0.400	1695.778	41.107	3389.919	0.791	0.028	0.421	0.722	0.484	99.837

51-195-460	0.000	448.667	84.829	1260.224	0.254	0.030	0.088	0.000	0.000	0.000
51-195-487	0.000	1211.667	60.736	2890.325	0.486	0.068	0.208	0.562	0.744	126.929
51-195-504	0.600	1019.667	45.791	2889.665	0.800	0.033	0.378	-0.323	-0.895	77.673
51-195-506	0.000	1874.778	108.079	3552.378	0.531	0.091	0.217	0.016	0.812	109.973
51-195-514	1.000	561.556	46.198	2521.714	0.829	0.009	0.351	0.190	-0.925	144.067
51-195-521	0.838	919.333	43.121	2822.197	0.854	0.009	0.476	0.171	-0.720	45.293
51-195-527	0.714	913.556	71.675	2825.763	0.841	0.023	0.347	0.648	0.099	99.927
51-195-541	0.143	1713.111	32.209	3182.484	0.741	0.035	0.332	-0.014	0.993	94.034
51-195-547	0.400	1739.444	59.328	2881.973	0.681	0.034	0.408	-0.428	0.844	31.391
51-195-548	0.000	1051.222	166.201	3790.813	0.206	0.046	0.065	-0.608	-0.774	89.621
51-195-553	0.448	1904.667	156.746	3083.252	0.739	0.041	0.356	0.354	-0.508	98.984
51-195-569	0.238	1468.889	42.899	3193.627	0.675	0.076	0.282	-0.475	0.604	27.276
51-195-571	0.848	973.111	76.511	2728.260	0.846	0.017	0.320	-0.170	-0.967	152.352
51-195-576	0.962	1296.889	67.617	2704.302	0.842	0.019	0.498	-0.873	-0.178	73.940
51-195-582	0.000	1985.111	82.417	3834.529	0.554	0.127	0.218	-0.092	0.988	147.125
51-195-589	0.000	2397.111	59.222	3415.636	0.799	0.010	0.346	0.351	0.899	163.105
51-195-598	0.952	2030.111	59.099	3862.440	0.873	0.005	0.377	-0.129	0.904	136.545
51-195-608	0.000	1277.444	65.184	3859.862	0.128	0.015	0.071	-0.867	-0.424	61.790
51-195-611	0.000	1681.000	160.636	4083.681	0.139	0.016	0.101	-0.580	0.649	106.373
51-195-617	0.905	1258.444	52.023	2702.886	0.819	0.012	0.438	0.779	0.449	45.888
51-195-629	0.010	608.778	86.386	3530.787	0.191	0.025	0.091	0.933	-0.225	92.338
51-195-638	0.971	1039.333	26.794	3000.296	0.847	0.007	0.420	0.277	-0.030	37.296
51-195-639	0.971	1568.778	76.274	3557.116	0.806	0.065	0.345	-0.720	-0.690	138.468
51-195-658	0.067	1541.556	46.897	3174.357	0.683	0.034	0.324	-0.139	0.930	77.420
51-195-695	0.000	1571.889	38.509	3187.717	0.516	0.070	0.247	0.725	0.673	16.225
51-27-1296	0.857	906.778	35.393	2706.118	0.842	0.018	0.391	0.813	0.571	170.215

51-27-1310	0.638	370.000	22.627	1993.547	0.810	0.021	0.279	0.610	-0.764	181.101
51-27-1333	0.495	1667.111	71.769	3369.403	0.700	0.067	0.269	-0.876	0.232	115.547
51-27-1340	0.686	1356.778	58.267	2769.876	0.765	0.037	0.341		-0.612	166.123
51-27-1350	0.790	1587.778	53.179	2911.681	0.791	0.044	0.393	-0.323	-0.255	130.001
51-27-1352	0.181	887.000	68.474	2445.234	0.710	0.084	0.249	0.510	-0.859	63.568
51-27-1421	0.143	1217.667	91.742	2159.492	0.481	0.220	0.229	-0.129	0.792	97.475
51-27-1431	0.533	1765.778	45.757	3139.493	0.804	0.010	0.420	-0.855	-0.226	132.532
51-27-1433	0.476	1785.889	46.926	3383.400	0.763	0.033	0.301	-0.625	0.517	87.311
51-27-1450	0.571	1065.667	69.200	3018.017	0.799	0.043	0.318	0.152	-0.813	84.850
51-27-1594	0.648	1317.111	94.928	2724.563	0.722	0.126	0.287	-0.167	-0.212	80.231
51-27-1620	0.838	1983.889	70.433	3466.605	0.834	0.016	0.332	-0.447	0.880	147.272
51-27-1638	0.705	588.667	79.423	2361.144	0.834	0.021	0.206	0.922	-0.250	158.697
51-27-1647	0.829	1449.222	86.999	3264.914	0.853	0.021	0.362	-0.373	0.646	135.824
51-27-1655	0.352	1532.556	63.046	2624.800	0.592	0.084	0.229	-0.645	0.738	109.429
51-27-1656	0.257	1443.000	357.570	2371.027	0.634	0.187	0.244	-0.789	-0.612	161.545
51-27-1670	0.857	370.000	23.726	2153.979	0.834	0.018	0.224	0.764	-0.408	186.979
51-27-1692	0.733	947.000	69.668	2480.891	0.670	0.090	0.324	-0.221	-0.953	124.740
51-51-1765	0.229	1422.778	28.443	2928.512	0.758	0.027	0.298	0.638	-0.242	25.035
51-51-1771	0.505	1815.000	42.489	3100.818	0.674	0.069	0.434	-0.841	-0.400	84.327
51-27-1772	0.724	789.556	72.234	2291.958	0.724	0.052	0.403	0.936	-0.189	115.179
51-51-1774	0.505	1027.667	137.398	2563.868	0.657	0.069	0.263	0.494	-0.281	72.840
51-51-1775	0.752	879.889	63.644	2847.556	0.810	0.018	0.369	0.427	0.424	116.634
51-51-1781	0.371	1184.667	92.151	2955.817	0.711	0.069	0.306	0.322	0.380	87.455
51-51-1784	0.048	1112.333	56.845	3390.099	0.708	0.061	0.300	0.528	0.083	54.490
51-51-1808	0.448	1388.444	99.914	2779.055	0.769	0.031	0.383	0.653	-0.756	86.130
51-51-1822	0.914	489.667	36.652	2374.065	0.840	0.012	0.253	0.415	-0.868	157.702

51-51-1849	0.895	834.000	63.019	2543.531	0.839	0.016	0.353	-0.242	-0.840	157.430
51-195-1896	0.181	1819.667	90.514	3476.812	0.714	0.063	0.287	0.350	0.421	42.926
51-195-1901	0.676	1674.889	57.966	3389.470	0.791	0.024	0.361	0.506	0.804	109.936
51-195-1953	0.000	2048.222	106.703	3437.458	0.718	0.017	0.349	-0.773	-0.223	32.442
51-51-2217	0.057	2122.333	62.034	3156.369	0.736	0.038	0.270	0.745	0.050	51.491
51-51-2219	0.048	1734.667	22.696	3506.045	0.602	0.094	0.355	-0.183	0.761	21.833
51-51-2226	0.048	1616.111	46.317	3219.731	0.692	0.023	0.320	0.483	0.712	91.023
51-195-2230	0.086	1581.778	36.640	3493.708	0.500	0.097	0.286	-0.394	-0.875	11.849
51-195-2234	0.029	1521.333	103.696	3437.831	0.732	0.046	0.325	-0.042	0.502	6.461
51-195-2238	0.305	2010.000	89.236	3598.751	0.775	0.060	0.331	-0.858	0.335	80.587
51-195-2250	0.914	1165.222	40.080	3152.781	0.826	0.015	0.400	0.319	-0.222	36.994
51-195-2253	0.886	1565.667	79.671	2857.382	0.819	0.037	0.363	0.373	0.123	76.751
51-195-2254	0.581	1384.667	69.356	3036.560	0.808	0.021	0.370	-0.308	-0.914	78.875
51-195-2266	0.429	847.333	39.397	2516.825	0.698	0.063	0.400	0.932	-0.246	89.743
51-195-2274	0.210	1662.667	28.534	3692.585	0.659	0.044	0.346	0.395	0.024	15.221
51-195-2275	0.019	1627.556	34.114	3029.237	0.586	0.030	0.277	0.980	0.158	23.164
51-195-2288	0.286	1917.111	156.209	3679.250	0.769	0.040	0.320	-0.069	0.980	53.361
51-195-2290	0.667	2128.778	51.567	3281.750	0.770	0.041	0.334	-0.779	0.587	60.820
51-195-2292	0.400	1349.778	63.491	2458.000	0.767	0.023	0.340	0.051	-0.940	129.500
51-195-2293	0.419	1343.556	28.099	3323.655	0.738	0.050	0.344	0.866	0.440	46.867
51-195-2296	0.771	1620.667	70.546	3156.578	0.815	0.026	0.341	-0.991	-0.016	79.303
51-195-2303	0.876	960.667	71.896	2542.240	0.808	0.015	0.440	0.939	-0.158	86.651
51-195-2312	0.714	1442.556	32.251	2990.475	0.807	0.022	0.376	-0.839	-0.508	96.609
51-195-2314	0.743	1433.000	59.712	2832.673	0.813	0.018	0.525	-0.649	-0.694	149.972
51-195-2315	0.924	958.111	38.563	2517.562	0.837	0.010	0.641	0.795	-0.596	71.545
51-195-2317	0.143	1925.111	65.754	3613.833	0.880	0.013	0.370	0.342	0.756	123.112

51-195-2326	0.686	1445.889	27.559	3062.886	0.794	0.039	0.362	0.155	0.979	35.045
51-195-2328	0.048	1364.556	133.387	3400.502	0.409	0.058	0.143	-0.704	0.305	57.389
51-195-2331	0.781	1370.889	25.631	3237.347	0.805	0.033	0.402	-0.657	0.446	110.910
51-195-2333	0.781	1238.556	121.704	2836.928	0.777	0.033	0.326	0.344	-0.120	92.072
51-195-2334	0.190	1339.333	308.356	3307.455	0.574	0.159	0.178	0.675	-0.725	93.638
51-195-2335	0.000	883.333	193.156	2784.169	0.124	0.009	0.063	0.087	0.616	104.424
51-195-2336	0.000	1788.556	75.581	3895.613	0.414	0.077	0.221	-0.240	0.954	66.005
51-195-2337	1.000	1184.778	57.282	3260.406	0.845	0.012	0.351	-0.122	0.550	19.932
51-195-2339	0.000	845.222	23.940	2696.867	0.162	0.010	0.105	0.021	-0.937	163.986
51-195-2340	0.000	1966.444	59.353	2891.949	0.553	0.036	0.319	-0.942	0.305	122.370
51-195-2638	0.000	1596.333	43.440	2886.050	0.644	0.077	0.294	-0.104	-0.928	51.390
51-195-2639	0.076	1484.333	63.486	2722.423	0.658	0.031	0.338	-0.283	-0.949	30.342
51-195-2642	0.543	516.111	60.936	2508.724	0.797	0.040	0.321	0.209	-0.813	133.782
51-195-2643	0.019	2194.556	60.002	3697.310	0.451	0.083	0.228	-0.856	0.420	93.097
51-195-2644	0.667	1561.333	52.484	3552.420	0.787	0.021	0.367	-0.893	-0.302	55.581
51-195-2665	0.000	1317.222	54.985	3346.761	0.130	0.014	0.076	0.518	0.625	105.387
51-195-2666	0.810	1693.111	76.099	3385.913	0.781	0.051	0.358	0.449	0.605	163.853

*FIPS codes: State level: 51-Virginia; County level: 51-Dickenson, 27-Buchanan, 195-Wise and 167-Russell.

Appendix F: Sample points in "Non-mined" category used to develop model (Chapter 5)

PROJID shows the unique number of photo-plot as Federal Information Processing Standards (FIPS) codes for State-County_PointID*, Ref. canopy is the Reference data developed by photo-interpretation. 2008 and 2009 represent leaf-on and leaf-off Landsat scenes respectively. "tc" denotes tasseled cap and "ndvi" represents Normalized difference vegetation index. Fcm and fst denote focal mean and focal standard deviation respectively.

PROJID	Ref.	2008 b4fst	2008 tc2fcm	2008 tc3fcm	2008 tc3fst	2009 tc2fcm	2009 tc3fcm	2008 ndvi fcm	2009 ndvifcm	Cos fcm	Sin fcm
51-27-1	0.91	112.01	1931.29	-133.45	42.17	477.24	-2310.12	0.85	0.38	-0.93	0.04
51-27-2	0.61	469.44	1665.96	158.04	58.21	86.55	-504.07	0.84	0.28	0.24	-0.72
51-27-3	0.80	167.30	1642.44	43.58	29.38	148.14	-535.81	0.84	0.32	-0.28	-0.80
51-27-5	0.43	231.47	2257.52	11.94	54.70	406.76	-2506.47	0.85	0.34	-0.48	0.86
51-27-6	0.78	127.62	1437.56	128.97	20.03	-6.58	-108.58	0.83	0.26	0.92	-0.33
51-27-8	0.80	89.63	1748.44	-176.02	50.67	345.42	-2006.98	0.83	0.35	-0.96	-0.06
51-27-9	0.72	143.86	1822.03	-102.42	55.85	268.86	-1328.42	0.83	0.36	0.32	0.90
51-27-10	0.94	109.65	2164.55	-184.84	21.85	500.13	-2374.86	0.85	0.38	-0.14	0.98
51-27-11	0.38	240.20	1399.90	99.18	69.94	13.58	-24.95	0.83	0.23	0.10	-0.97
51-27-12	0.97	82.73	2133.93	49.48	66.34	408.99	-1840.39	0.85	0.37	0.05	0.98
51-27-13	0.67	397.62	1616.22	72.68	53.14	98.48	-477.24	0.84	0.32	0.76	-0.61
51-27-16	0.84	156.79	2138.17	156.19	46.98	372.02	-1431.82	0.86	0.36	-0.36	-0.23
51-27-17	0.80	304.74	1872.09	-69.81	60.63	328.35	-1310.51	0.83	0.35	-0.24	0.42
51-27-18	0.96	276.90	2099.05	184.60	47.94	320.78	-1320.39	0.86	0.35	-0.45	0.32

51-27-20	0.72	144.63	1669.44	198.59	44.84	72.44	-219.06	0.85	0.32	0.22	-0.95
51-27-21	0.83	140.21	1358.47	-1.39	56.37	-0.78	-148.34	0.82	0.23	0.72	-0.64
51-27-22	0.74	270.79	1820.52	8.26	52.19	326.83	-1454.64	0.85	0.36	-0.05	0.80
51-27-23	0.82	244.59	1376.06	40.32	35.00	-21.97	2.63	0.82	0.20	0.95	-0.22
51-27-24	0.76	293.13	1970.43	-310.67	208.15	558.49	-1919.12	0.78	0.38	-0.92	0.18
51-27-26	0.84	455.40	1842.28	140.45	34.47	153.72	-539.58	0.85	0.36	0.99	-0.10
51-27-27	0.85	301.01	2221.87	97.06	44.15	507.31	-1716.89	0.86	0.43	-0.48	0.85
51-27-28	0.49	169.44	2367.70	77.94	63.80	596.58	-2496.50	0.86	0.39	-0.73	0.65
51-27-30	0.89	163.63	1747.30	68.80	35.45	209.31	-888.83	0.84	0.38	0.67	0.72
51-27-31	0.76	130.66	2373.25	124.12	39.47	430.37	-2014.80	0.87	0.37	-0.66	0.28
51-27-32	0.81	279.54	2048.41	189.99	45.67	271.33	-972.87	0.85	0.39	-0.15	-0.36
51-27-34	0.50	653.92	1671.43	-64.10	166.48	122.41	-560.02	0.79	0.31	0.53	0.01
51-27-35	0.79	100.35	2609.80	179.00	34.36	566.04	-2465.85	0.88	0.37	-0.81	0.57
51-27-36	0.90	96.00	2362.28	100.48	40.87	557.97	-2121.96	0.87	0.40	-0.69	0.59
51-27-37	0.90	193.08	1443.15	1.61	40.01	113.06	-447.73	0.82	0.36	-0.08	-0.90
51-27-38	0.66	99.36	1894.69	-73.42	97.49	368.23	-1600.56	0.81	0.34	-0.92	-0.08
51-27-39	0.75	447.20	1826.81	147.95	49.46	155.56	-699.47	0.86	0.33	0.46	0.03
51-27-40	0.50	314.86	2049.05	211.53	46.89	306.70	-921.67	0.85	0.36	0.01	-0.20
51-27-41	0.85	361.77	1914.78	149.64	33.05	250.34	-730.92	0.85	0.38	-0.57	-0.69
51-27-42	0.65	287.36	1589.68	207.29	49.96	121.71	-117.02	0.83	0.38	0.92	-0.23
51-27-43	0.74	291.67	1558.77	-131.70	158.27	287.35	-1023.77	0.79	0.34	-0.46	-0.78
51-27-44	0.93	244.29	1975.63	123.18	31.12	155.69	-682.04	0.84	0.31	0.72	0.43
51-27-45	0.46	142.00	2309.78	-40.62	40.99	439.18	-1955.91	0.85	0.39	-0.03	0.99
51-27-46	0.73	147.78	2465.29	236.94	37.47	451.89	-2004.01	0.88	0.37	-0.67	0.63
51-27-47	0.77	161.52	1741.98	162.53	39.99	94.93	-409.20	0.85	0.32	0.74	-0.54
51-27-50	0.64	138.76	1683.96	-16.20	282.12	265.35	-874.67	0.75	0.33	-0.03	-0.27
51-27-51	0.91	188.86	1624.48	-31.49	37.97	264.59	-1016.83	0.83	0.37	-0.45	-0.84

51-27-52	0.68	150.84	2100.95	99.31	46.68	402.86	-1714.22	0.86	0.38	-0.60	0.19
51-27-53	0.96	156.17	2396.11	222.71	45.76	525.63	-1759.43	0.85	0.39	-0.88	0.34
51-27-55	0.22	244.78	1515.57	137.87	103.31	94.66	-354.31	0.82	0.34	0.05	-0.98
51-27-56	0.67	149.14	1513.22	-49.15	110.05	174.54	-352.84	0.77	0.34	0.96	0.17
51-27-59	0.80	288.43	1998.96	-203.35	36.16	369.48	-2073.36	0.83	0.37	-0.50	0.81
51-27-60	0.72	270.55	2052.71	38.02	82.07	500.48	-1050.90	0.82	0.42	-0.60	-0.04
51-27-61	0.57	225.01	1863.35	-205.90	303.63	715.16	-855.94	0.77	0.49	-0.32	-0.64
51-27-62	0.80	419.38	1882.50	-29.68	73.00	223.70	-1456.35	0.84	0.33	-0.21	-0.22
51-27-63	0.91	126.04	1549.94	31.26	61.28	138.99	-485.03	0.83	0.34	-0.01	-0.99
51-27-64	0.89	280.84	2187.52	135.55	40.09	367.60	-1585.86	0.86	0.35	-0.80	-0.12
51-27-66	0.55	75.29	1937.54	280.10	55.97	155.49	-436.48	0.86	0.36	0.05	-0.82
51-27-67	0.75	431.56	1819.88	136.38	76.22	170.77	-656.21	0.84	0.37	0.59	-0.12
51-27-68	0.88	153.41	1976.12	244.10	55.68	171.78	-660.93	0.85	0.34	0.91	0.27
51-27-69	0.90	83.70	1801.31	-96.62	71.16	316.31	-1177.52	0.84	0.38	-0.64	-0.76
51-27-70	0.07	256.69	1406.33	68.09	118.63	90.66	-315.02	0.80	0.35	0.15	-0.97
51-27-71	0.69	287.31	1554.05	19.21	78.37	32.88	-212.75	0.83	0.29	0.84	-0.31
51-27-72	0.67	319.05	2156.19	184.38	48.76	341.55	-1025.27	0.86	0.38	0.03	0.54
51-27-73	0.74	161.37	2381.06	-11.10	42.14	517.02	-2405.42	0.85	0.37	-0.87	0.39
51-27-74	0.86	417.54	1586.57	108.37	63.59	86.25	-223.35	0.83	0.36	0.93	0.17
51-27-75	0.39	234.80	1842.62	-26.36	144.72	343.93	-990.21	0.82	0.38	-0.74	-0.64
51-27-76	0.82	294.91	1551.45	-22.29	37.85	204.78	-159.24	0.82	0.41	-0.18	-0.88
51-27-77	0.52	250.60	1629.63	102.44	54.10	168.46	-469.46	0.83	0.38	0.04	-0.96
51-27-78	0.74	276.65	2280.81	169.46	67.95	458.13	-1210.03	0.86	0.37	-0.52	0.62
51-27-79	0.55	187.15	1558.48	128.88	60.65	27.64	-112.52	0.84	0.27	0.60	-0.75
51-27-80	0.00	213.59	2065.25	22.69	47.88	357.19	-1361.61	0.85	0.38	0.36	0.93
51-27-82	0.95	444.76	2020.40	64.98	293.82	295.53	-1171.03	0.81	0.32	0.44	0.89
51-27-83	0.90	300.51	1886.39	38.19	32.62	304.39	-1067.59	0.84	0.39	-0.67	-0.64

51-27-84	0.48	176.32	1954.83	76.60	187.26	314.50	-1027.38	0.79	0.35	-0.41	-0.50
51-27-85	0.67	189.86	1588.21	58.75	90.92	68.33	-205.79	0.83	0.31	0.90	0.11
51-27-86	0.96	184.59	1699.57	146.21	43.17	190.82	-447.99	0.84	0.42	-0.25	-0.96
51-27-87	0.89	116.20	2201.38	0.82	70.27	539.33	-1941.74	0.85	0.39	-0.79	0.44
51-27-88	0.62	126.91	2525.79	202.33	70.53	465.86	-1784.10	0.87	0.37	-0.08	0.97
51-27-89	0.54	186.89	2012.60	50.10	64.92	336.20	-1246.44	0.85	0.36	-0.91	-0.31
51-27-90	0.82	303.69	1662.21	104.32	73.56	131.95	-470.15	0.84	0.36	0.83	0.43
51-27-91	0.94	381.19	1440.32	88.33	62.67	70.95	-186.48	0.83	0.36	0.77	-0.42
51-27-92	0.93	40.89	1957.37	-163.89	22.57	434.94	-2261.42	0.84	0.37	-0.69	0.47
51-27-93	0.38	553.66	1933.02	-38.08	141.31	330.88	-1448.93	0.79	0.39	-0.12	0.31
51-27-94	0.59	273.20	2277.19	-26.57	103.58	426.94	-1723.43	0.84	0.40	0.27	0.87
51-27-95	0.25	324.06	1333.20	154.10	43.80	46.03	-54.40	0.83	0.32	0.25	-0.91
51-27-96	0.03	122.49	2504.79	91.98	58.72	462.39	-2037.87	0.87	0.37	-0.33	0.93
51-27-97	0.93	325.55	1960.44	91.22	68.90	423.25	-951.58	0.84	0.45	-0.60	-0.46
51-27-98	0.94	122.20	1619.57	127.74	40.98	123.42	-329.52	0.84	0.37	0.01	-0.92
51-27-99	0.88	319.51	1916.25	62.55	37.61	280.03	-940.60	0.85	0.36	-0.71	-0.64
51-27-100	0.86	143.90	2299.43	241.30	50.59	365.63	-1463.65	0.86	0.35	-0.85	-0.39
51-27-101	0.76	216.70	2404.42	209.53	83.44	472.09	-1590.06	0.87	0.38	-0.88	0.32
51-27-102	0.93	206.35	1584.53	211.26	48.90	81.83	-151.27	0.84	0.35	0.67	-0.61
51-27-103	0.96	577.72	2002.90	164.36	30.47	310.24	-1100.94	0.84	0.35	-0.45	-0.31
51-27-104	0.89	229.59	1533.34	-46.59	57.75	84.63	-380.64	0.82	0.32	0.86	0.49
51-27-105	0.67	190.98	1634.79	-32.23	261.39	227.10	-795.96	0.78	0.35	0.35	-0.70
51-27-106	0.83	445.16	1302.66	125.90	105.97	10.26	-62.05	0.82	0.23	0.50	-0.86
51-27-107	0.68	189.63	1651.10	-46.90	151.46	292.70	-929.84	0.82	0.36	-0.40	-0.89
51-27-108	0.86	366.47	1567.04	181.06	69.34	83.42	-89.71	0.85	0.32	0.85	-0.16
51-27-109	0.89	125.23	2042.41	-74.02	39.48	501.27	-1864.48	0.84	0.41	-0.12	0.98
51-27-110	0.70	279.81	1482.55	-15.63	56.48	121.86	-329.97	0.82	0.34	0.96	0.03

51-27-111	0.83	283.53	2177.90	-87.01	143.20	502.96	-2060.50	0.82	0.36	-0.37	0.83
51-27-112	0.81	340.24	1457.91	108.39	66.08	33.97	-81.23	0.82	0.28	0.95	-0.18
51-27-115	0.77	292.50	1944.52	83.35	57.07	175.47	-1098.25	0.85	0.34	0.42	0.89
51-27-116	0.53	199.11	1717.91	177.61	75.06	127.77	-388.17	0.84	0.37	0.15	-0.86
51-27-119	0.49	364.24	1527.13	18.28	159.02	268.26	-746.93	0.78	0.40	-0.17	-0.88
51-27-121	0.62	385.88	1774.01	136.68	100.96	133.07	-295.78	0.86	0.35	0.97	-0.21
51-27-122	0.14	166.02	1115.83	-22.17	42.56	-28.97	101.52	0.80	0.17	0.48	-0.79
51-27-124	0.95	376.38	2154.02	93.48	72.80	756.87	-931.62	0.84	0.56	-0.54	0.68
51-27-125	0.87	140.97	1819.21	-28.95	29.03	375.13	-1366.28	0.84	0.39	-0.83	-0.46
51-27-126	0.29	459.36	1880.50	-59.04	104.76	291.96	-880.56	0.83	0.40	0.11	-0.32
51-27-127	0.74	301.13	1533.13	-50.95	84.90	360.39	-510.41	0.80	0.50	-0.45	-0.34
51-27-128	0.84	143.11	1666.52	173.50	67.12	38.27	-167.82	0.84	0.29	0.41	-0.77
51-27-129	0.72	100.34	1718.85	108.32	118.65	163.74	-432.61	0.83	0.32	0.77	0.45
51-27-131	0.77	125.50	1901.54	158.04	56.27	126.46	-419.35	0.85	0.36	0.89	0.37
51-27-133	0.73	125.21	1597.31	170.83	35.15	37.93	-13.77	0.84	0.29	0.95	-0.14
51-27-134	0.89	157.52	1143.19	119.92	54.09	-15.16	14.28	0.82	0.25	0.50	-0.70
51-27-136	0.70	329.73	1987.98	226.37	105.46	158.88	-677.99	0.84	0.32	0.74	0.14
51-27-137	0.89	126.92	1419.11	22.69	30.28	46.49	-257.44	0.81	0.33	0.21	-0.95
51-27-138	0.88	146.36	2026.33	221.54	43.30	327.17	-959.63	0.85	0.38	-0.81	-0.54
51-27-141	0.53	221.23	2217.75	33.55	101.00	396.07	-1620.22	0.86	0.36	-0.79	-0.50
51-27-142	0.62	345.19	1727.09	40.78	91.25	155.06	-466.82	0.84	0.39	0.89	0.37
51-27-143	0.62	240.22	1940.49	159.59	44.24	212.17	-743.15	0.85	0.36	-0.36	-0.84
51-27-144	0.77	118.79	1606.74	47.51	52.25	120.93	-222.46	0.83	0.40	0.97	0.11
51-27-145	0.92	177.19	2145.59	18.57	18.92	407.09	-1700.51	0.85	0.38	-0.12	0.94
51-27-148	0.71	212.94	2047.58	120.59	79.45	315.41	-1272.12	0.85	0.36	-0.09	0.85
51-27-149	0.61	270.32	1983.35	-270.53	332.06	490.64	-1829.22	0.80	0.39	-0.96	0.01
51-27-150	0.80	332.78	2210.99	275.23	65.89	298.38	-1002.09	0.86	0.37	-0.49	-0.76

51-27-151	0.84	326.20	2206.59	131.29	96.28	537.07	-1328.45	0.86	0.42	-0.84	-0.21
51-27-153	0.77	159.29	2021.27	-11.26	106.82	411.35	-1560.32	0.82	0.37	-0.94	0.11
51-27-154	0.69	127.53	2079.12	-170.21	66.76	396.39	-1731.76	0.83	0.39	0.17	0.97
51-27-155	0.49	473.70	1272.33	74.71	122.14	-23.79	-13.93	0.76	0.23	0.82	-0.55
51-27-156	0.88	273.04	1388.26	60.32	82.34	51.76	-266.08	0.81	0.34	0.21	-0.93
51-27-158	0.79	124.65	2313.59	139.79	29.61	463.88	-2029.72	0.86	0.39	-0.81	-0.30
51-27-163	0.61	688.97	1885.59	-36.60	73.10	391.93	-1198.72	0.79	0.37	-0.25	0.72
51-27-164	0.23	437.85	1422.62	-287.13	231.97	781.87	-752.70	0.69	0.52	-0.52	0.45
51-27-166	0.67	203.11	1473.43	-12.08	64.46	20.35	-209.94	0.82	0.28	0.96	0.28
51-27-167	0.28	234.49	1866.99	-142.31	218.92	689.18	-898.82	0.76	0.45	0.23	0.89
51-27-168	0.78	486.72	1880.33	268.20	165.78	178.81	-535.26	0.83	0.35	0.55	-0.62
51-27-169	0.90	244.08	2209.17	-65.97	51.27	626.25	-2341.15	0.84	0.41	-0.60	0.79
51-27-171	0.22	622.70	1680.48	-22.43	116.00	152.87	-728.96	0.77	0.28	0.39	-0.34
51-27-173	0.89	317.59	2297.95	24.73	70.39	518.66	-2084.99	0.86	0.37	-0.92	0.22
51-27-175	0.61	350.09	1355.81	47.15	91.83	20.48	26.64	0.82	0.28	0.72	-0.66
51-27-176	0.86	67.17	2193.48	-85.67	44.72	563.96	-2260.76	0.85	0.41	-0.44	0.84
51-27-178	0.82	146.56	1788.51	144.50	49.31	37.98	-182.49	0.85	0.27	0.99	0.12
51-27-180	0.90	205.22	2445.65	147.33	77.70	604.55	-1846.67	0.87	0.41	-0.71	0.64
51-27-185	0.91	485.62	1957.40	136.02	32.64	120.88	-443.10	0.85	0.33	0.86	0.47
51-27-186	0.33	126.13	1899.60	-250.83	240.53	461.49	-2082.25	0.79	0.38	-0.26	0.95
51-27-188	0.87	221.90	2087.40	-166.51	46.06	552.92	-2318.00	0.82	0.41	-0.57	0.78
51-27-189	0.90	398.50	1461.89	-45.64	70.56	131.46	-388.59	0.77	0.36	0.93	0.26
51-27-191	0.82	171.20	2197.31	68.12	58.34	328.03	-1534.59	0.85	0.37	0.54	0.59
51-27-193	0.95	218.21	2509.52	278.20	64.52	401.98	-1752.38	0.87	0.36	-0.23	0.97
51-27-196	0.92	527.04	1749.77	108.89	37.61	114.05	-648.11	0.85	0.30	-0.03	-0.40
51-27-198	0.83	481.39	2172.08	21.98	58.63	527.20	-1672.93	0.84	0.39	-0.92	0.08
51-27-199	0.88	431.28	2095.35	-27.29	64.60	375.84	-1757.80	0.85	0.38	-0.46	-0.07

51-27-201	0.90	212.55	1559.24	82.94	44.23	28.97	-143.93	0.83	0.29	0.37	-0.93
51-27-203	0.53	320.00	1792.92	111.70	65.20	169.71	-694.21	0.82	0.31	0.07	-0.94
51-27-204	0.93	407.03	1761.78	38.54	33.80	326.31	-893.19	0.83	0.38	-0.15	-0.64
51-27-206	0.79	136.57	1870.67	-48.81	50.55	590.91	-944.50	0.83	0.49	-0.96	-0.25
51-27-209	0.08	111.26	1808.91	-472.45	141.61	410.95	-1055.22	0.72	0.30	0.84	0.26
51-27-211	0.81	339.68	1945.65	196.25	82.53	180.76	-656.65	0.85	0.38	0.52	0.15
51-27-214	0.77	253.54	1686.85	173.90	80.95	68.75	-275.38	0.83	0.29	0.63	-0.67
51-27-216	0.75	327.70	2378.89	200.03	59.26	454.36	-1778.93	0.87	0.39	-0.77	-0.03
51-27-217	0.75	98.53	2099.10	-121.49	59.76	662.25	-1424.22	0.84	0.47	-0.72	0.54
51-27-219	0.78	441.12	1880.09	218.82	102.27	226.76	-599.80	0.81	0.32	0.06	-0.44
51-27-221	0.70	85.84	2171.43	305.61	41.37	217.90	-381.74	0.87	0.34	0.21	-0.68
51-27-222	0.95	204.83	1815.12	46.24	52.78	235.97	-979.27	0.84	0.34	-0.64	-0.74
51-27-224	0.81	673.22	1990.43	191.46	62.63	789.21	-1264.21	0.84	0.52	-0.53	-0.10
51-27-228	0.62	309.57	1338.01	-78.82	269.66	73.43	-460.60	0.76	0.31	0.21	-0.94
51-27-230	0.74	155.71	1454.97	104.97	69.03	11.39	-12.93	0.81	0.27	0.93	-0.34
51-27-233	0.46	236.25	1724.23	-137.20	118.35	584.55	-1091.42	0.77	0.47	-0.45	0.30
51-27-235	0.24	503.39	1652.04	85.60	101.67	118.53	-464.00	0.83	0.32	0.31	-0.93
51-27-238	0.80	330.31	1446.03	219.54	65.83	99.44	-350.57	0.84	0.32	0.27	-0.91
51-27-244	0.81	299.11	1902.72	28.72	79.06	251.06	-861.71	0.83	0.34	0.71	0.49
51-27-248	0.92	247.61	2150.18	65.93	54.43	338.88	-1438.35	0.85	0.39	0.33	0.88
51-27-250	0.59	321.81	1838.77	7.28	107.08	305.18	-952.63	0.80	0.37	-0.17	-0.28
51-27-259	0.81	238.91	2350.13	50.84	46.85	728.64	-1548.71	0.85	0.46	-0.49	0.71
51-27-265	0.75	169.42	1913.53	194.04	37.14	81.51	-432.13	0.85	0.32	0.98	0.11
51-27-271	0.74	199.71	2155.33	107.57	110.92	391.38	-1176.58	0.82	0.34	-0.41	0.41
51-27-275	0.91	378.93	1913.64	84.12	61.42	352.54	-879.88	0.84	0.42	-0.24	-0.77
51-27-277	0.55	275.19	2216.92	126.44	94.62	316.65	-1355.67	0.83	0.33	0.27	0.95
51-27-281	0.30	498.30	1357.50	-147.28	263.43	334.66	-497.32	0.67	0.37	-0.33	0.10

51-27-288	0.89	200.88	1375.87	115.84	38.14	1.31	70.61	0.84	0.30	0.47	-0.87
51-27-294	0.97	184.94	1885.74	241.00	61.55	226.62	-539.98	0.85	0.38	-0.19	-0.96
51-27-300	0.93	390.48	1695.50	102.04	72.37	184.95	-530.78	0.83	0.37	0.66	0.54
51-27-304	0.92	169.33	1501.37	107.71	41.62	35.65	-191.85	0.84	0.31	0.48	-0.84
51-27-307	0.84	389.83	2243.72	297.67	63.63	319.15	-986.37	0.85	0.37	-0.60	-0.47
51-27-325	0.85	257.87	1782.45	134.05	63.24	126.64	-328.57	0.85	0.36	0.71	-0.21
51-27-332	0.87	250.94	2182.13	267.24	50.88	327.20	-797.61	0.86	0.38	-0.58	-0.66
51-27-343	0.82	347.07	2277.90	274.92	47.84	332.74	-1022.68	0.86	0.37	-0.31	-0.37
51-27-350	0.70	302.99	2640.85	113.27	51.22	609.95	-1435.94	0.87	0.41	-0.25	0.92
51-27-376	0.10	359.75	2079.72	-132.18	99.35	260.93	-1155.48	0.78	0.32	0.83	0.39
51-51-113	0.94	99.25	1910.08	195.93	27.90	298.69	-616.32	0.85	0.46	0.60	0.02
51-51-118	0.84	543.29	1875.30	99.36	57.97	258.84	-1127.95	0.85	0.37	0.57	0.58
51-51-130	0.92	134.11	2371.41	206.55	39.98	458.57	-1131.83	0.86	0.43	-0.22	0.97
51-51-135	0.93	157.65	1344.76	-23.65	47.14	-20.76	-3.93	0.82	0.21	0.79	-0.54
51-51-140	0.93	406.23	1997.25	174.64	61.78	323.40	-1108.11	0.84	0.38	-0.69	-0.10
51-51-147	0.90	153.95	2143.37	7.57	78.17	524.57	-1992.19	0.84	0.37	-0.80	0.28
51-51-152	0.90	346.57	1542.43	-42.49	30.09	326.09	-559.09	0.82	0.48	-0.73	-0.38
51-51-157	0.88	144.15	1488.86	92.91	28.18	-24.83	-46.40	0.83	0.20	0.85	-0.52
51-51-160	0.95	84.20	2185.44	122.26	33.10	533.14	-933.55	0.85	0.51	-0.78	-0.17
51-51-162	0.84	426.51	2114.62	35.87	81.31	214.25	-1091.28	0.84	0.34	0.36	0.83
51-51-165	0.31	651.67	1864.71	-159.10	131.77	471.21	-1227.36	0.76	0.34	0.37	-0.29
51-51-170	0.72	445.94	1963.65	-217.55	97.16	801.85	-2218.57	0.83	0.47	-0.60	0.51
51-51-174	0.96	110.91	1105.28	-93.22	97.94	78.49	-72.92	0.76	0.37	0.96	0.08
51-51-177	0.96	101.03	2438.25	160.99	37.12	537.35	-1682.40	0.86	0.42	-0.12	0.99
51-51-179	0.90	230.66	1871.31	109.00	100.39	147.00	-749.81	0.84	0.32	-0.18	-0.63
51-51-182	0.88	110.45	1909.58	-160.80	36.37	668.75	-937.46	0.82	0.53	-0.83	0.45
51-51-184	0.42	209.25	1875.49	-304.94	203.43	663.68	-1915.12	0.74	0.42	-0.25	0.93

51-51-187	0.00	19.00	77.06	120.63	12.31	-379.74	268.85	0.48	-0.42	0.00	0.00
51-51-190	0.97	149.96	2231.26	239.16	57.25	360.62	-730.40	0.86	0.45	-0.59	0.42
51-51-192	0.87	268.37	1485.88	-135.88	38.10	215.47	-716.28	0.81	0.40	0.72	-0.26
51-51-195	0.96	57.89	2063.66	54.74	53.64	562.58	-1382.11	0.83	0.44	-0.88	0.46
51-51-197	0.73	244.63	1531.85	-132.95	97.69	362.55	-933.67	0.80	0.46	-0.13	0.55
51-51-200	0.21	76.85	1526.10	-738.70	379.11	614.29	-1171.03	0.62	0.37	-0.50	0.54
51-51-202	0.39	393.92	1562.78	-357.91	223.47	364.86	-1453.64	0.74	0.36	-0.73	-0.54
51-51-205	0.25	204.18	1531.89	-405.03	296.98	710.24	-896.14	0.68	0.40	-0.92	-0.28
51-51-207	0.87	209.45	1818.27	56.35	35.49	331.27	-826.55	0.83	0.42	-0.69	-0.34
51-51-208	0.99	83.35	2401.42	259.53	28.59	560.69	-809.64	0.86	0.53	0.25	0.91
51-51-210	0.90	170.39	2048.08	13.47	40.17	391.08	-1513.00	0.85	0.37	-0.81	0.09
51-51-212	0.91	191.15	1334.26	24.23	39.93	93.50	-100.95	0.80	0.37	0.98	0.12
51-51-213	0.94	229.00	1549.33	61.42	43.49	147.94	-541.64	0.82	0.37	0.03	-0.97
51-51-215	0.95	378.19	1530.56	-52.93	40.41	160.28	-536.16	0.82	0.36	-0.58	-0.71
51-51-218	0.90	96.16	2019.54	-129.78	50.79	465.98	-1926.53	0.85	0.40	-0.89	0.34
51-51-220	0.91	179.03	1809.38	95.35	54.66	176.70	-736.07	0.85	0.36	0.61	-0.06
51-51-223	0.87	269.83	1401.56	36.10	97.00	104.96	-426.11	0.81	0.32	0.13	-0.97
51-51-225	0.52	223.22	1740.96	-178.26	216.74	404.74	-1099.74	0.79	0.39	-0.15	0.59
51-51-226	0.98	259.19	1924.90	168.92	54.68	314.23	-652.64	0.85	0.47	-0.62	-0.56
51-51-229	0.83	144.82	1850.57	-102.00	19.51	421.48	-861.41	0.83	0.47	0.52	0.47
51-51-231	0.90	169.60	1492.32	-16.76	30.98	193.81	-85.31	0.82	0.48	0.61	-0.52
51-51-232	0.93	289.82	1555.23	50.38	46.00	170.61	-380.84	0.82	0.36	0.62	-0.76
51-51-236	0.94	116.17	1721.24	-35.24	62.29	229.43	-821.61	0.83	0.37	-0.48	-0.86
51-51-239	0.84	271.69	1830.02	158.36	56.40	148.61	-600.08	0.84	0.36	0.78	0.37
51-51-242	0.78	302.58	1795.15	-128.80	47.71	356.24	-973.68	0.81	0.42	0.48	0.80
51-51-246	0.90	330.17	1857.05	38.45	44.13	472.86	-724.96	0.83	0.48	-0.20	-0.44
51-51-249	0.80	292.39	1717.05	-87.93	49.75	209.42	-882.69	0.82	0.38	0.08	0.67

51-51-251	0.73	180.47	1895.90	25.75	65.12	212.49	-1142.09	0.85	0.37	0.56	0.81
51-51-255	0.83	102.38	1924.76	-24.92	104.89	497.68	-1486.56	0.84	0.45	-0.94	-0.19
51-51-257	0.58	295.54	1416.47	-113.35	139.32	181.72	-518.68	0.73	0.35	0.10	-0.88
51-51-258	0.83	253.63	1298.62	-50.31	53.10	91.90	-257.83	0.80	0.31	0.41	-0.88
51-51-263	0.78	209.23	1834.67	-88.14	31.06	600.78	-793.22	0.83	0.55	-0.55	-0.16
51-51-264	0.74	175.71	1936.03	88.27	38.55	283.97	-1146.93	0.84	0.36	0.59	0.65
51-51-266	0.86	159.74	1536.90	48.82	45.97	23.99	-151.74	0.83	0.24	0.64	-0.70
51-51-269	0.75	269.04	1498.69	84.66	40.42	80.44	-360.71	0.82	0.29	0.96	-0.14
51-51-270	0.83	259.15	2128.11	120.88	73.91	513.82	-1424.67	0.85	0.43	0.08	0.98
51-51-273	0.71	119.23	1755.16	-69.79	79.65	234.08	-1012.09	0.82	0.36	0.80	0.45
51-51-276	0.71	258.24	2091.14	-110.20	108.16	452.72	-1601.63	0.82	0.40	0.47	0.85
51-51-282	0.61	342.45	1944.56	-215.60	88.64	503.73	-1997.60	0.83	0.41	-0.23	0.97
51-51-285	0.86	147.23	2200.46	149.49	37.43	443.34	-1242.47	0.86	0.43	-0.75	-0.39
51-51-289	0.87	135.34	1478.51	99.30	78.48	40.85	-152.15	0.83	0.32	0.23	-0.95
51-51-292	0.44	306.49	1720.49	-47.54	124.63	404.72	-754.72	0.76	0.37	-0.20	-0.13
51-51-295	0.75	274.62	2018.18	153.59	72.56	261.66	-1050.77	0.84	0.36	0.71	0.50
51-51-298	0.71	171.17	2198.37	115.54	43.57	346.76	-1451.37	0.86	0.34	0.32	0.89
51-51-299	0.84	227.15	1623.65	-17.32	35.48	292.90	-808.99	0.83	0.36	0.57	-0.36
51-51-301	0.72	289.13	2034.98	247.01	87.00	148.78	-668.95	0.86	0.38	0.71	-0.21
51-51-302	0.83	191.95	1732.61	-83.62	63.96	288.66	-1116.87	0.79	0.37	-0.38	-0.92
51-51-305	0.20	170.41	1996.16	-18.45	74.45	332.28	-821.63	0.81	0.35	0.29	-0.30
51-51-308	0.84	409.38	2137.37	261.05	42.70	399.51	-804.68	0.87	0.38	-0.16	-0.58
51-51-309	0.70	322.91	1860.19	-33.74	62.09	283.56	-1423.44	0.84	0.37	-0.13	-0.09
51-51-312	0.76	102.34	1764.48	157.58	44.64	152.73	-503.82	0.85	0.34	0.17	-0.76
51-51-315	0.72	221.70	1426.80	-170.12	98.41	260.18	-662.39	0.78	0.41	-0.34	-0.86
51-51-316	0.70	153.66	1978.92	-51.21	91.97	346.81	-1364.90	0.83	0.37	0.04	0.94
51-51-319	0.56	108.20	1579.40	69.97	36.77	220.43	-619.90	0.84	0.40	-0.26	-0.96

51-51-322	0.89	196.37	1614.02	167.25	31.70	8.73	-87.97	0.83	0.25	0.90	-0.37
51-51-323	0.81	116.07	2380.11	-25.79	35.09	540.24	-2328.58	0.87	0.38	-0.26	0.86
51-51-326	0.88	202.70	1965.49	190.87	68.97	194.76	-649.48	0.85	0.38	0.58	-0.54
51-51-330	0.93	105.80	1916.50	200.84	35.78	190.46	-404.86	0.86	0.39	0.28	-0.92
51-51-341	0.94	236.85	1751.61	5.58	31.75	135.21	-616.52	0.84	0.35	0.83	0.20
51-51-344	0.86	112.48	2188.71	5.45	59.61	474.14	-2169.50	0.85	0.37	-0.66	0.48
51-51-348	0.97	254.32	1635.30	-49.56	21.52	287.62	-511.83	0.83	0.48	0.51	-0.55
51-51-351	0.85	92.12	2123.38	-58.82	59.33	519.08	-1725.14	0.84	0.42	0.21	0.97
51-51-354	0.88	176.70	2363.40	171.42	43.59	510.84	-1592.95	0.87	0.40	-0.69	-0.34
51-51-363	0.90	179.42	2533.69	253.63	49.11	634.21	-1572.05	0.87	0.42	-0.56	0.72
51-51-366	0.83	492.36	1970.55	5.61	75.04	421.71	-1387.80	0.84	0.37	-0.15	0.30
51-51-370	0.89	224.40	1521.09	101.30	36.40	91.86	-116.56	0.83	0.36	0.35	-0.94
51-51-373	0.80	311.65	1887.27	154.28	50.98	86.42	-449.16	0.85	0.32	0.94	0.14
51-51-377	0.80	263.97	2061.77	179.33	76.85	208.92	-815.28	0.85	0.35	0.26	0.59
51-51-380	0.84	413.38	2304.56	278.91	43.50	250.36	-881.00	0.85	0.32	-0.85	-0.14
51-51-381	0.92	225.25	1449.85	-59.94	48.16	381.75	-253.95	0.81	0.57	-0.35	-0.91
51-51-388	0.90	382.12	2296.49	253.62	49.28	302.73	-1149.70	0.86	0.37	-0.40	-0.86
51-51-389	0.81	132.94	1587.25	-24.28	47.15	327.88	-235.17	0.83	0.47	1.00	0.03
51-51-397	0.82	107.08	2319.50	-16.16	46.93	792.33	-1920.18	0.85	0.46	-0.99	0.06
51-51-400	0.76	182.13	2598.05	219.98	74.48	461.08	-1591.77	0.88	0.39	-0.10	0.34
51-51-404	0.89	289.67	2116.61	255.67	50.93	321.39	-535.48	0.85	0.44	-0.35	-0.86
51-51-407	0.87	258.85	1866.39	183.07	57.02	132.03	-552.12	0.84	0.33	-0.18	-0.76
51-51-408	0.87	223.35	2089.97	-69.31	75.74	836.54	-1205.18	0.83	0.51	-0.84	-0.27
51-51-411	0.94	184.50	2104.08	-11.00	86.45	468.74	-1912.72	0.85	0.38	-0.90	-0.24
51-51-414	0.90	261.35	2472.64	284.11	48.91	351.76	-1343.97	0.87	0.36	0.47	0.84
51-51-419	0.74	160.05	2460.66	194.67	77.40	684.97	-1356.16	0.86	0.47	-0.14	0.97
51-51-423	0.95	132.27	1746.96	19.02	50.10	296.59	-507.75	0.84	0.50	-0.12	-0.99

51-51-431	0.24	172.00	1882.64	-287.15	168.51	430.72	-979.70	0.77	0.36	0.81	0.23
51-51-451	0.92	202.47	2103.14	245.40	70.00	182.34	-618.00	0.86	0.37	0.83	0.14
51-51-455	0.90	432.89	2107.10	250.22	54.90	154.49	-506.64	0.86	0.37	0.80	0.03
51-51-459	0.93	305.99	1855.43	169.26	37.43	308.03	-494.72	0.84	0.43	-0.25	-0.80
51-51-462	0.88	170.63	2102.63	191.55	98.91	289.21	-845.18	0.86	0.37	-0.03	-0.15
51-51-473	0.67	225.14	2089.72	104.20	59.19	536.58	-553.63	0.85	0.54	0.63	0.75
51-51-481	0.92	205.09	1802.87	211.39	53.93	133.55	-378.81	0.85	0.33	0.07	-0.97
51-51-489	0.90	515.66	1993.12	53.55	353.36	336.78	-1093.34	0.81	0.34	0.27	0.87
51-51-500	0.76	249.07	2529.28	219.49	24.41	663.46	-1780.01	0.86	0.41	-0.78	0.60
51-51-516	0.83	261.69	2763.21	291.44	50.29	516.22	-2061.29	0.88	0.37	-0.25	0.92
51-195-283	0.78	83.58	2413.78	147.61	46.89	576.87	-1333.88	0.86	0.44	-0.70	0.49
51-195-290	0.99	195.02	2046.94	78.79	46.48	486.01	-1296.12	0.85	0.43	-0.74	0.47
51-195-296	0.91	333.60	1786.51	129.89	29.12	170.67	-345.08	0.83	0.36	0.62	0.00
51-195-306	0.81	112.15	2407.76	103.64	67.08	907.52	-1346.12	0.83	0.52	-0.87	0.41
51-195-313	0.70	294.61	1945.47	-39.70	86.45	547.18	-1454.60	0.84	0.45	0.15	0.67
51-195-320	0.79	165.77	1703.70	-6.99	177.60	579.91	-779.31	0.81	0.51	-0.88	-0.35
51-195-331	0.96	88.00	2235.72	144.49	25.59	656.37	-1060.15	0.85	0.48	-0.95	0.22
51-195-338	0.38	283.41	1468.29	-409.49	378.83	683.86	-1400.95	0.64	0.45	-0.34	0.88
51-195-357	0.96	222.50	2052.28	143.43	49.53	321.79	-715.39	0.85	0.45	0.47	0.54
51-195-360	0.78	158.55	2058.16	115.40	47.62	198.08	-890.77	0.85	0.36	0.88	0.45
51-195-364	0.48	508.65	613.51	121.41	139.93	-65.56	-60.84	0.67	0.10	0.73	-0.36
51-195-378	0.64	374.99	1784.84	80.34	79.76	252.60	-598.22	0.83	0.39	-0.41	-0.80
51-195-391	0.91	177.41	2026.53	7.25	64.61	454.71	-1279.26	0.85	0.43	0.03	0.91
51-195-398	0.95	316.12	2124.13	179.81	45.31	314.02	-885.94	0.85	0.39	-0.15	0.32
51-195-401	0.84	328.66	1459.95	89.40	33.34	209.42	-258.34	0.81	0.41	-0.06	-0.72
51-195-405	0.94	113.59	1886.11	-5.27	51.67	287.42	-861.15	0.83	0.39	-0.70	-0.71
51-195-417	0.83	257.50	2036.70	71.51	68.56	425.50	-1030.33	0.84	0.44	-0.42	-0.61

51-195-425	0.79	357.86	1787.84	103.48	41.41	197.23	-570.90	0.84	0.40	-0.23	-0.82
51-195-440	0.85	298.53	2469.20	138.72	123.46	498.02	-1740.73	0.86	0.39	-0.28	0.94
51-195-448	0.14	168.77	1648.56	-106.92	123.37	331.01	-877.82	0.73	0.37	0.88	0.46
51-195-463	0.98	183.27	1992.13	164.89	52.62	349.55	-743.11	0.85	0.43	-0.45	-0.88
51-195-467	0.71	257.90	2157.51	80.30	176.58	856.07	-665.54	0.80	0.54	-0.65	0.03
51-195-470	0.82	462.79	2027.52	-128.69	285.00	496.65	-1279.31	0.80	0.44	0.37	0.86
51-195-474	0.99	173.42	2077.50	185.98	55.39	228.09	-776.88	0.85	0.36	-0.44	-0.88
51-195-477	0.90	145.66	2291.17	289.03	49.94	351.32	-687.52	0.86	0.44	0.25	-0.62
51-195-485	0.99	148.13	2115.37	284.32	16.29	254.94	-546.19	0.86	0.41	0.22	-0.92
51-195-512	0.93	308.19	2148.17	218.76	135.62	387.77	-1048.04	0.86	0.38	0.36	0.43
51-195-517	0.11	334.16	1310.26	-282.10	156.56	495.45	-753.18	0.60	0.37	0.28	-0.71
51-195-520	0.91	368.55	2045.87	104.57	159.36	319.32	-1043.71	0.85	0.40	0.56	-0.53
51-195-531	0.94	142.44	2303.65	207.92	65.30	300.92	-800.39	0.85	0.40	0.83	0.54
51-195-535	0.91	410.74	1664.06	159.36	69.21	366.76	-962.62	0.66	0.36	-0.11	0.55
51-195-536	0.93	231.57	2077.48	164.07	26.33	345.12	-664.47	0.85	0.49	-0.58	-0.77
51-195-544	0.48	347.13	2352.14	-42.61	220.32	445.03	-1931.69	0.83	0.35	-0.67	0.16
51-195-550	0.97	189.89	2229.47	127.98	60.37	336.00	-1401.63	0.86	0.36	-0.85	-0.41
51-195-551	0.25	302.77	1547.56	-169.24	165.79	493.03	-903.45	0.64	0.38	0.04	0.88
51-195-555	0.81	239.75	2375.80	176.64	46.97	546.29	-1734.56	0.86	0.36	-0.70	0.37
51-195-556	0.92	98.91	2435.32	195.79	29.74	736.38	-935.25	0.86	0.56	-0.73	0.65
51-195-559	0.01	69.76	1817.47	-433.93	111.45	767.01	-984.92	0.67	0.36	0.72	0.58
51-195-563	0.97	114.22	1933.84	138.09	91.04	208.25	-813.14	0.85	0.39	-0.30	-0.94
51-195-564	0.96	230.59	1855.57	61.28	108.22	345.74	-486.21	0.83	0.49	-0.43	-0.74
51-195-567	0.47	195.64	1699.72	-65.71	180.81	461.45	-806.93	0.72	0.38	0.54	0.79
51-195-572	0.09	308.58	1957.22	-349.54	93.32	909.93	-853.72	0.74	0.47	-0.27	0.93
51-195-575	0.88	255.40	2593.84	318.22	63.46	491.59	-1367.31	0.87	0.39	-0.76	0.18
51-195-579	0.90	159.42	2483.77	263.79	67.65	342.37	-1004.15	0.87	0.39	0.31	0.94

51-195-583	0.88	112.10	2151.16	115.90	79.33	478.29	-1385.36	0.84	0.39	-0.89	0.31
51-195-586	0.98	51.87	1615.27	98.12	34.16	43.21	-308.95	0.84	0.27	0.93	-0.36
51-195-591	0.90	149.95	2723.06	341.71	74.24	506.44	-1937.54	0.88	0.37	-0.76	0.37
51-195-595	0.80	185.27	1976.42	180.21	74.97	476.94	-615.65	0.84	0.47	-0.33	-0.89
51-195-596	1.00	203.39	1797.31	138.59	58.00	198.73	-732.85	0.82	0.38	-0.42	-0.90
51-195-599	0.90	314.61	1929.37	209.15	52.03	119.34	-466.01	0.85	0.37	0.92	-0.05
51-195-602	0.56	346.17	2296.49	-119.99	157.16	502.58	-1894.28	0.82	0.36	-0.60	-0.01
51-195-603	0.90	357.98	1465.36	153.52	65.67	14.14	-148.51	0.82	0.31	0.79	-0.60
51-195-605	0.87	119.41	1948.76	95.97	86.34	307.93	-1192.12	0.85	0.37	-0.78	-0.55
51-195-610	0.43	389.84	1376.02	-146.44	185.65	491.31	-913.27	0.69	0.38	-0.10	0.02
51-195-613	0.93	95.64	2227.47	173.90	63.96	400.06	-1521.70	0.84	0.38	-0.82	0.16
51-195-614	1.00	151.38	2068.64	219.60	15.42	215.02	-567.72	0.85	0.40	-0.72	-0.44
51-195-618	0.88	150.74	1936.32	2.18	95.96	470.28	-629.53	0.83	0.51	-0.45	-0.72
51-195-621	0.84	188.88	1960.92	192.10	25.43	116.92	-394.06	0.85	0.35	0.99	-0.04
51-195-624	0.92	105.95	1933.92	73.67	52.48	457.39	-915.42	0.84	0.46	0.19	0.71
51-195-625	0.95	220.01	2145.36	136.66	50.96	432.15	-953.71	0.85	0.43	-0.83	-0.49
51-195-628	0.92	96.65	2055.53	243.30	33.30	231.23	-590.33	0.85	0.35	0.83	-0.16
51-195-634	0.47	304.22	1761.94	-89.32	190.35	427.22	-1242.07	0.73	0.36	-0.03	0.29
51-195-641	1.00	67.23	2288.49	228.67	42.46	317.31	-1015.91	0.86	0.38	0.91	0.18
51-195-642	0.94	355.36	1490.13	75.71	63.38	361.76	-532.15	0.84	0.54	0.93	0.23
51-195-645	0.96	478.34	2232.60	162.10	59.16	480.99	-1206.10	0.86	0.40	0.08	0.35
51-195-646	0.90	64.15	2545.08	257.39	33.87	350.54	-1335.76	0.87	0.38	-0.08	0.75
51-195-648	0.85	170.99	2060.92	130.70	78.95	513.23	-1216.57	0.82	0.39	0.23	0.39
51-195-651	0.89	183.01	2257.70	143.02	56.15	482.80	-1393.77	0.84	0.36	0.03	0.95
51-195-654	0.86	465.80	2006.72	181.41	95.83	344.85	-1201.07	0.85	0.34	0.23	-0.80
51-195-655	0.91	338.26	2240.04	207.65	36.01	260.91	-937.71	0.86	0.40	-0.37	-0.04
51-195-657	0.85	106.22	2107.41	233.31	33.27	497.99	-556.44	0.84	0.52	-0.17	-0.97

51-195-660	0.70	479.16	1478.49	-94.18	97.46	145.08	-744.87	0.77	0.26	0.00	0.00
51-195-663	0.98	199.08	1904.89	265.40	120.46	605.18	-1759.54	0.61	0.41	-0.50	0.80
51-195-667	0.86	191.59	2771.88	288.23	71.94	408.87	-1332.62	0.86	0.35	-0.17	0.98
51-195-670	0.93	211.95	2024.23	157.15	40.33	268.16	-306.40	0.85	0.50	0.85	-0.34
51-195-672	0.99	168.59	2521.37	256.97	41.50	504.95	-1009.61	0.86	0.42	-0.42	0.40
51-195-673	0.91	278.01	2195.05	107.86	78.30	477.91	-1223.01	0.84	0.42	-0.59	-0.49
51-195-675	0.06	119.02	1750.60	-489.04	111.88	645.03	-1279.01	0.70	0.36	-0.51	-0.21
51-195-677	0.92	343.60	2439.58	188.74	75.54	493.67	-706.49	0.87	0.45	0.10	0.62
51-195-680	0.88	99.98	1889.03	110.39	24.75	153.28	-323.51	0.85	0.39	0.90	-0.44
51-195-682	1.00	278.97	1908.64	213.52	49.74	44.83	-147.71	0.85	0.35	0.87	-0.42
51-195-685	0.87	75.41	2923.24	235.58	61.19	501.45	-2059.44	0.87	0.37	-0.95	-0.05
51-195-687	0.92	197.05	2470.94	288.87	47.96	523.94	-2064.86	0.87	0.39	-0.97	0.20
51-195-692	0.10	292.83	1634.26	-995.22	120.46	685.85	-2558.60	0.64	0.34	-0.78	0.07
51-195-696	0.83	141.46	1851.40	181.43	39.76	33.36	-48.91	0.86	0.29	0.40	-0.85
51-195-698	0.90	75.42	1538.34	-2.12	28.72	88.95	-322.40	0.82	0.35	-0.05	-0.99
51-195-700	0.83	149.00	2250.69	77.80	53.49	798.11	-931.60	0.85	0.54	-0.75	0.62
51-195-702	0.10	260.77	290.39	-603.08	92.79	-78.13	-899.60	0.33	0.20	0.86	-0.47
51-195-707	1.00	296.24	1774.72	73.35	97.00	184.59	-644.97	0.84	0.33	0.64	-0.65
51-195-710	0.93	177.03	1663.78	113.48	56.76	103.86	-310.11	0.83	0.37	0.66	-0.62
51-195-712	0.87	120.00	1718.29	238.32	52.02	53.14	52.30	0.84	0.43	0.52	-0.81
51-195-714	1.00	103.11	2528.31	221.21	37.58	780.65	-868.87	0.87	0.56	-0.17	0.99
51-195-716	0.59	1070.14	1299.17	-105.50	139.94	621.37	-495.67	0.73	0.50	-0.35	0.76
51-195-719	0.24	304.30	1058.64	-284.58	80.61	203.86	-837.20	0.59	0.32	0.87	-0.23
51-195-721	0.96	98.15	1969.47	86.90	58.07	313.70	-1084.95	0.85	0.40	0.79	0.56
51-195-723	0.94	273.72	2123.07	196.50	34.12	150.10	-657.74	0.86	0.36	0.83	0.54
51-195-725	1.00	124.87	2308.93	231.16	31.10	409.65	-935.32	0.86	0.44	-0.34	0.20
51-195-727	0.87	194.97	2053.15	208.30	62.81	296.04	-788.85	0.85	0.38	-0.01	-0.91

51-195-729	0.92	93.61	2105.07	12.59	66.88	548.40	-1506.90	0.84	0.43	-0.99	-0.04
51-195-732	0.88	281.83	2289.24	223.70	47.97	469.45	-1192.57	0.86	0.41	-0.18	0.85
51-195-734	0.97	63.52	2351.74	172.76	36.45	551.67	-1481.48	0.86	0.39	-0.59	0.80
51-195-736	0.99	191.73	2406.85	223.19	54.62	380.38	-1076.02	0.86	0.39	-0.26	0.90
51-195-741	0.83	115.31	1454.27	139.00	25.39	6.77	-3.37	0.84	0.24	0.26	-0.96
51-167-227	0.98	287.03	2439.03	281.68	42.71	379.67	-1276.19	0.86	0.37	-0.16	0.55
51-167-241	0.82	186.13	1895.88	170.04	135.73	228.34	-636.75	0.79	0.33	-0.16	-0.82
51-167-247	0.96	187.46	1973.17	129.78	33.61	343.18	-871.74	0.84	0.39	-0.68	-0.71
51-167-253	0.51	225.82	1742.22	24.36	113.35	147.83	-524.56	0.81	0.30	0.73	-0.03
51-167-256	0.64	346.83	1926.95	155.14	141.40	158.13	-382.37	0.85	0.35	0.91	0.22
51-167-262	0.43	319.94	1664.59	132.33	148.66	273.84	-603.33	0.71	0.31	-0.48	-0.46
51-167-268	0.56	337.45	1769.73	-146.38	139.43	453.02	-1140.04	0.76	0.38	-0.28	0.48
51-167-274	0.90	278.69	2002.17	179.85	61.38	334.54	-829.97	0.84	0.35	0.42	0.64
51-167-280	0.51	221.92	1693.25	-88.26	131.86	536.26	-1180.85	0.73	0.38	-0.84	-0.14
51-167-284	0.54	413.37	1772.52	144.20	79.35	220.48	-538.15	0.84	0.38	-0.03	-0.96
51-167-287	1.00	237.66	2063.06	74.36	62.71	427.94	-1758.09	0.84	0.37	-0.34	0.62
51-167-310	1.00	208.21	1879.95	75.51	122.74	290.91	-1073.89	0.82	0.35	-0.65	-0.74
51-167-314	1.00	154.88	2659.08	337.01	33.92	440.89	-1315.37	0.87	0.39	-0.74	0.38
51-167-317	0.90	170.84	1399.69	91.13	43.71	64.32	-248.49	0.81	0.31	0.23	-0.96
51-167-321	0.77	243.25	2108.78	211.81	87.28	460.18	-973.21	0.85	0.44	-0.70	-0.39
51-167-324	1.00	154.44	2290.79	144.23	47.12	401.56	-1997.90	0.85	0.35	-0.86	0.48
51-167-328	0.00	310.67	1925.83	235.70	36.71	83.51	-271.54	0.87	0.32	0.86	-0.49
51-167-335	0.84	210.10	1781.47	-52.08	70.29	470.26	-1281.13	0.81	0.38	-0.91	-0.36
51-167-339	0.87	189.18	2102.51	157.06	83.94	359.57	-1092.91	0.85	0.39	-0.70	-0.30
51-167-342	0.87	162.01	2082.78	15.40	125.25	479.76	-1951.42	0.83	0.33	-0.90	0.43
51-167-346	0.19	353.35	2407.04	16.62	91.42	656.28	-992.60	0.81	0.38	-0.95	-0.17
51-167-349	0.99	111.97	1873.44	-481.74	50.71	739.50	-1064.92	0.75	0.40	0.79	0.51

51-167-353	0.74	178.39	2064.25	-315.97	73.56	647.61	-1772.84	0.77	0.35	-0.96	0.19
51-167-356	0.20	293.20	1693.47	-309.14	99.59	259.02	-845.03	0.74	0.32	0.07	0.12
51-167-365	0.48	391.12	2162.07	-257.06	371.40	495.86	-1602.19	0.77	0.34	-0.55	0.83
51-167-368	0.59	314.21	2023.80	-362.67	407.54	376.14	-1850.07	0.79	0.35	-0.46	0.53
51-167-372	0.81	206.63	1609.47	-223.83	117.59	260.01	-1265.18	0.75	0.31	-0.91	0.14
51-167-375	0.67	225.47	1609.97	33.32	88.26	241.81	-533.85	0.81	0.38	0.92	0.11
51-167-379	0.37	168.99	1924.34	-387.65	442.16	310.33	-1532.26	0.78	0.35	-0.29	0.62
51-167-382	0.78	178.89	1595.19	-24.62	138.91	299.51	-646.65	0.79	0.38	0.03	-0.61
51-167-384	0.79	314.21	2266.21	192.34	62.34	460.98	-864.21	0.86	0.48	-0.03	0.98
51-167-387	0.09	316.49	1382.19	-255.29	101.91	141.54	-573.74	0.71	0.25	0.22	-0.96
51-167-390	0.00	118.30	1239.05	-492.59	92.83	418.97	-540.90	0.63	0.33	0.97	-0.25
51-167-392	0.34	172.71	1679.76	-450.69	243.04	471.22	-1438.13	0.72	0.34	-0.72	-0.18
51-167-395	0.22	298.56	2070.15	-403.38	119.47	557.68	-1484.54	0.74	0.36	-0.85	0.22
51-167-396	0.70	345.69	2318.80	137.49	67.04	362.04	-1057.33	0.86	0.41	0.34	0.77
51-167-399	0.47	360.40	1953.90	-12.22	44.33	323.53	-1226.68	0.84	0.38	0.24	0.49
51-167-402	0.88	203.78	1714.51	149.20	113.78	179.68	-405.79	0.84	0.42	0.85	-0.34
51-167-406	0.04	266.05	1303.06	-290.32	190.99	142.81	-395.88	0.69	0.28	0.94	-0.13
51-167-409	0.00	167.78	1334.55	-478.55	163.84	323.45	-877.39	0.63	0.31	-0.07	-0.86
51-167-410	0.88	471.88	2269.11	184.52	45.30	444.73	-1151.60	0.86	0.43	0.23	0.09
51-167-413	0.96	97.55	2154.61	114.98	36.02	252.17	-1265.11	0.86	0.34	0.51	0.85
51-167-416	0.00	112.70	1897.10	-306.92	125.39	547.28	-985.45	0.74	0.32	0.32	-0.70
51-167-421	0.41	277.90	1510.02	-505.35	211.00	730.42	-995.20	0.69	0.44	0.55	0.34
51-167-422	0.84	238.27	1849.59	62.08	54.30	149.41	-581.00	0.84	0.36	0.55	-0.24
51-167-424	0.81	177.84	1756.21	204.42	107.82	98.20	-442.10	0.85	0.33	0.72	-0.37
51-167-426	0.90	201.90	1702.39	129.25	48.77	154.07	-558.28	0.84	0.32	-0.39	-0.91
51-167-429	0.42	117.84	1295.37	-325.82	122.05	337.49	-860.28	0.68	0.31	-0.13	-0.98
51-167-430	0.95	335.04	1871.75	248.82	49.24	154.10	-205.41	0.84	0.40	0.65	-0.69

51-167-432	0.75	109.37	2323.08	269.76	31.86	-373.57	-983.20	0.86	0.14	-0.64	-0.69
51-167-434	0.04	357.21	1862.67	-241.71	157.98	523.80	-696.87	0.72	0.36	0.88	-0.34
51-167-437	0.00	168.12	1922.79	-360.81	146.41	694.08	-1032.70	0.73	0.36	-0.27	-0.75
51-167-438	1.00	92.43	1936.17	163.88	72.19	242.28	-571.14	0.85	0.43	-0.07	-0.90
51-167-441	0.91	160.39	1716.62	129.21	40.83	113.85	-313.64	0.83	0.34	0.98	0.13
51-167-444	0.06	91.09	1930.21	-242.43	76.52	526.66	-895.31	0.73	0.33	0.88	0.30
51-167-446	0.00	235.74	2829.69	49.11	74.98	661.95	-898.97	0.84	0.38	-0.25	0.77
51-167-449	0.44	197.40	1286.83	-276.79	206.66	426.67	-695.87	0.75	0.46	-0.05	-0.93
51-167-452	0.93	144.12	1602.34	170.65	26.01	170.49	-257.45	0.84	0.84	0.07	-0.98
51-167-454	0.96	172.14	1985.26	4.38	43.24	378.82	-1387.30	0.84	0.37	-0.67	-0.11
51-167-457	0.86	256.03	2314.04	314.06	109.84	1018.11	-694.44	0.85	0.58	-0.92	-0.16
51-167-461	0.45	485.36	1346.29	-57.15	152.50	58.73	4.22	0.75	0.22	0.53	-0.84
51-167-465	0.93	194.68	1607.24	224.75	30.75	6.72	-38.11	0.84	0.28	0.72	-0.63
51-167-468	0.95	150.29	1571.73	34.75	43.17	192.70	-689.72	0.82	0.33	-0.29	-0.94
51-167-471	0.50	356.72	1781.35	-45.93	162.64	395.77	-638.09	0.80	0.43	0.24	-0.94
51-167-475	0.69	78.38	1770.78	166.11	62.43	222.46	-765.73	0.84	0.38	0.22	-0.75
51-167-478	1.00	45.18	2312.12	303.04	35.35	310.86	-339.97	0.85	0.43	-0.34	-0.93
51-167-480	0.00	297.18	1921.12	-375.97	265.40	407.93	-1150.07	0.73	0.34	0.25	-0.92
51-167-483	0.00	174.96	2087.89	-95.20	85.15	490.96	-1292.31	0.74	0.29	-0.81	-0.18
51-167-484	0.94	93.85	1957.37	68.56	63.94	398.44	-1329.71	0.84	0.40	-0.82	-0.56
51-167-486	1.00	122.11	2425.14	260.29	33.98	-529.35	-1296.40	0.85	0.12	-0.56	0.72
51-167-488	0.93	61.33	1787.53	-116.93	31.00	493.94	-1486.05	0.81	0.43	-0.98	-0.14
51-167-491	0.75	322.45	2050.57	51.56	162.16	606.46	-1926.28	0.82	0.36	-0.63	0.77
51-167-492	0.82	171.10	2611.53	238.75	54.32	485.34	-1840.31	0.87	0.37	-0.73	0.66
51-167-495	0.04	107.50	1940.63	-239.81	91.91	787.78	-749.60	0.76	0.43	0.52	-0.82
51-167-496	0.78	245.57	2359.62	188.06	30.04	437.78	-1457.24	0.87	0.38	-0.59	0.41
51-167-498	0.46	172.85	2058.20	-39.79	60.64	342.60	-926.46	0.82	0.37	0.77	0.07

51-167-499	0.16	154.30	1647.55	-543.26	183.09	530.31	-1407.16	0.70	0.35	-0.80	-0.17
51-167-502	0.09	126.17	1504.98	-690.98	141.71	626.30	-1588.03	0.66	0.38	-0.42	-0.40
51-167-503	0.82	318.81	2130.47	244.04	66.32	95.93	-389.85	0.86	0.28	0.89	0.25
51-167-505	0.91	129.60	2158.09	164.32	21.73	589.24	-132.40	0.84	0.61	-0.77	0.62
51-167-507	0.06	472.67	1771.03	-668.84	229.72	620.81	-1783.10	0.71	0.36	-0.88	-0.30
51-167-510	0.05	486.77	1703.16	-280.93	72.63	1263.36	-442.63	0.70	0.52	0.41	0.37
51-167-513	1.00	81.27	2567.13	273.07	35.63	167.79	-1092.19	0.86	0.27	-0.29	0.75
51-167-515	0.34	375.24	1986.23	-245.69	118.93	289.34	-838.04	0.79	0.33	0.70	0.68
51-167-518	0.06	316.22	1609.10	-453.05	177.68	516.94	-1359.31	0.70	0.30	-0.61	-0.77
51-167-522	0.44	275.22	2116.80	-219.62	97.94	531.52	-1336.06	0.80	0.40	0.08	0.99
51-167-525	0.74	108.02	1851.98	208.36	68.19	156.65	-681.83	0.84	0.34	0.86	0.46
51-167-526	0.85	420.78	2523.84	266.80	67.52	347.47	-1131.60	0.86	0.38	-0.07	0.73
51-167-529	0.32	191.13	1393.73	-618.96	194.63	432.90	-1622.84	0.68	0.38	-0.19	-0.65
51-167-530	0.86	165.66	2297.46	265.44	59.74	398.38	-1124.70	0.86	0.38	-0.73	0.05
51-167-532	0.89	354.24	2560.87	145.67	44.56	551.11	-2205.74	0.84	0.34	-0.48	0.82
51-167-534	0.88	248.60	1568.55	201.13	39.07	-1.79	-194.72	0.85	0.27	0.64	-0.75
51-167-537	0.46	437.67	1785.36	-139.99	158.43	398.44	-1172.19	0.77	0.35	-0.68	-0.70
51-167-538	0.91	261.20	2344.63	211.45	80.23	500.57	-1463.64	0.86	0.43	-0.34	0.86
51-167-540	0.00	157.07	2470.91	201.86	56.53	402.08	-1704.28	0.85	0.38	0.01	0.97
51-167-542	0.87	126.60	2343.86	143.85	110.70	454.98	-1589.77	0.87	0.37	-0.92	-0.37
51-167-545	0.02	62.53	1777.99	-358.23	58.36	470.68	-2118.52	0.75	0.30	-0.34	0.87
51-167-546	0.54	114.76	1383.68	-281.13	146.23	220.71	-728.34	0.74	0.35	0.43	-0.04
51-167-549	0.26	303.41	1440.16	-379.89	280.93	537.99	-1182.80	0.66	0.37	-0.57	-0.10
51-167-554	0.89	332.95	1570.72	123.74	67.54	165.72	-703.20	0.81	0.31	-0.30	-0.93
51-167-557	0.81	188.44	1792.66	-71.71	178.10	213.92	-1296.88	0.82	0.32	0.54	0.16
51-167-558	0.90	202.32	2241.16	281.71	66.31	410.32	-1065.40	0.87	0.38	-0.71	-0.67
51-167-560	0.86	119.54	1817.83	121.13	29.28	66.69	-175.04	0.82	0.27	0.69	-0.58

51-167-562	0.90	277.09	2123.63	66.77	157.28	246.51	-1283.70	0.85	0.33	-0.29	-0.06
51-167-565	0.33	255.32	1602.43	-284.79	158.04	307.02	-1025.28	0.75	0.30	0.29	0.52
51-167-566	0.82	92.15	2446.08	90.48	28.82	676.18	-2433.75	0.86	0.39	-0.85	0.52
51-167-568	0.80	262.99	1971.88	-28.82	39.80	381.11	-1760.49	0.81	0.34	-0.76	-0.06
51-167-570	0.61	281.49	1741.16	-18.75	150.20	175.93	-532.76	0.80	0.36	0.72	-0.65
51-167-573	0.15	171.68	1365.46	-682.50	157.60	663.32	-952.85	0.63	0.36	0.42	-0.84
51-167-577	0.00	165.08	1485.63	-795.70	144.12	556.60	-1405.05	0.64	0.35	-0.75	-0.64
51-167-580	0.76	188.84	1767.79	106.89	47.66	108.48	-78.83	0.82	0.41	0.89	0.18
51-167-581	0.05	237.34	1370.99	-836.99	156.58	619.64	-2067.18	0.62	0.35	-0.84	-0.43
51-167-585	0.24	185.31	760.24	-609.39	233.84	345.69	-996.83	0.47	0.33	-0.32	0.92
51-167-588	0.84	234.50	1977.47	70.64	93.07	255.09	-993.69	0.83	0.36	0.00	0.00
51-167-590	0.04	122.69	1434.93	-601.51	153.20	408.46	-912.75	0.69	0.37	0.85	-0.44
51-167-593	0.19	242.35	1631.50	-360.73	223.47	529.77	-620.66	0.71	0.38	0.37	-0.35
51-167-594	0.05	72.17	1550.74	-926.69	101.86	502.39	-1327.24	0.64	0.34	0.40	0.66
51-167-597	0.79	164.79	2235.44	194.18	104.60	330.74	-1527.29	0.84	0.35	-0.26	0.91
51-167-600	0.02	125.32	1936.69	-314.82	70.05	550.78	-1019.56	0.72	0.29	0.78	-0.30
51-167-601	0.94	152.85	1910.49	42.18	86.96	268.17	-1074.34	0.84	0.36	-0.43	-0.77
51-167-604	0.05	74.60	1455.88	-1032.16	114.48	776.48	-1670.32	0.59	0.34	-0.84	0.53
51-167-607	0.65	201.79	1445.94	206.10	68.02	46.27	50.80	0.84	0.32	0.00	0.00
51-167-609	0.43	660.97	1904.29	126.90	129.80	533.00	-868.00	0.80	0.40	-0.93	0.29
51-167-612	0.15	172.74	1157.23	-395.81	146.42	297.68	-848.30	0.62	0.31	0.42	-0.62
51-167-616	0.30	321.94	1678.37	-350.37	138.88	496.61	-557.04	0.75	0.41	0.27	-0.54
51-167-619	0.03	204.36	1885.48	-388.75	77.99	570.08	-912.57	0.75	0.33	0.00	0.00
51-167-620	0.12	232.58	1045.40	-607.79	328.04	287.17	-1342.99	0.52	0.28	-0.83	-0.30
51-167-622	0.13	241.10	1743.64	-567.72	150.46	515.29	-1318.81	0.70	0.33	0.70	0.21
51-167-626	0.78	142.55	2087.09	318.13	44.01	183.31	-216.46	0.85	0.43	0.00	0.00
51-167-627	0.26	679.32	1221.58	-134.39	198.76	148.00	-825.94	0.68	0.27	0.31	0.04

51-167-630	0.00	135.21	1953.59	-512.52	67.11	758.02	-1019.68	0.72	0.37	0.14	-0.58
51-167-633	0.00	196.03	1306.66	-848.74	142.73	751.00	-950.43	0.61	0.42	-0.21	-0.94
51-167-636	0.51	315.85	2016.34	-234.64	185.40	437.20	-1275.98	0.79	0.40	0.00	0.00
51-167-640	0.76	355.96	1407.85	99.76	81.41	-7.06	29.74	0.81	0.22	0.59	-0.79
51-167-643	0.00	350.85	1268.13	-658.51	169.48	479.22	-1181.71	0.57	0.29	0.00	0.00
51-167-644	0.90	304.89	1651.58	-71.06	41.30	671.75	-769.85	0.80	0.58	-0.24	0.96
51-167-647	0.27	360.74	1659.11	-485.35	273.61	449.99	-1455.25	0.69	0.32	-0.92	-0.16
51-167-650	0.05	119.31	1482.16	-589.76	164.81	529.48	-1221.91	0.67	0.37	0.19	-0.49
51-167-653	0.52	317.67	1492.12	-277.43	164.44	552.33	-1135.06	0.74	0.41	0.00	0.00
51-167-656	0.83	127.19	1841.56	-65.56	164.44	537.92	-1285.01	0.80	0.46	-0.37	0.81
51-167-659	0.00	198.21	1198.51	-878.51	315.50	559.47	-1045.17	0.49	0.33	0.00	0.00
51-167-662	0.75	228.45	2322.08	125.48	96.73	264.38	-1411.61	0.85	0.35	0.28	0.95
51-167-665	0.17	231.04	1513.61	-533.77	112.82	534.43	-1171.20	0.67	0.38	0.00	0.00
51-167-666	0.48	454.60	1326.50	-169.25	228.41	129.12	-41.83	0.71	0.23	0.69	-0.67
51-167-668	0.00	89.88	1607.73	-339.11	131.44	251.26	-910.67	0.73	0.27	0.48	-0.77
51-167-671	0.00	180.64	1242.67	-979.91	290.14	584.05	-1925.18	0.59	0.36	-0.17	0.09
51-167-676	0.94	304.81	1783.54	119.51	88.95	122.60	-457.93	0.84	0.32	0.61	-0.32
51-167-679	0.16	287.56	2281.40	12.38	195.40	454.31	-993.06	0.79	0.35	0.00	0.00
51-167-681	0.49	192.86	1885.89	81.00	182.22	163.04	-660.25	0.82	0.34	0.90	-0.34
51-167-683	0.12	467.39	1579.36	-255.32	153.18	299.66	-1287.68	0.66	0.27	0.00	0.00
51-167-684	0.70	308.52	1738.53	-254.96	233.41	831.33	-1270.72	0.78	0.51	-0.59	0.75
51-167-686	0.17	127.46	1735.71	-464.69	198.45	888.98	-1154.12	0.74	0.38	-0.71	-0.39
51-167-688	0.93	127.61	1600.46	190.23	39.96	17.56	-163.43	0.84	0.26	0.00	0.00
51-167-689	1.00	295.03	1977.53	233.16	37.70	142.02	-491.44	0.85	0.30	0.81	-0.15
51-167-691	0.70	555.39	1652.10	-40.09	267.34	597.29	-695.01	0.78	0.49	-0.90	0.02
51-167-693	0.94	380.52	1692.16	255.37	79.60	60.22	-127.51	0.85	0.26	0.50	-0.63
51-167-694	0.86	284.55	1154.16	165.58	52.39	28.83	-35.60	0.78	0.24	0.00	0.00

51-167-697	0.32	238.93	1632.90	-788.71	234.05	522.26	-1464.97	0.70	0.37		-0.71	-0.09
51-167-699	0.46	542.23	1893.67	105.06	105.57	289.44	-759.60	0.80	0.31		0.00	0.00
51-167-701	0.00	43.76	1191.36	-1172.03	60.01	776.61	-1194.91	0.57	0.38		-0.84	0.04
51-167-704	0.34	198.91	1644.07	-274.41	144.29	390.71	-1482.34	0.73	0.34		-0.36	-0.25
51-167-706	0.64	301.36	1817.80	-112.18	228.19	412.65	-1538.96	0.81	0.36		-0.79	-0.58
51-167-709	0.88	281.11	2202.88	240.28	50.07	201.27	-938.64	0.86	0.33		-0.21	-0.88
51-167-713	0.62	243.28	1825.46	-116.31	257.77	390.50	-1029.46	0.73	0.32		-0.44	-0.85

*FIPS codes: State level: 51-Virginia; County level: 51-Dickenson, 27-Buchanan, 195-Wise and 167-Russell.

Appendix G: Sample points in "Mixed" category used to develop model (Chapter 5)

Sample points from "Mixed" category used to develop the non-mined model (Chapter 5). PROJID shows the unique number of photo-plot as FIPS codes for State-County_PointID, Ref. is the Reference data developed by photo-interpretation. 2008 represents leaf-on, and 2009 represents leaf-off Landsat scenes. "tc" denotes Tasseled cap and "ndvi" represents Normalized Difference Vegetation Index. Fcm and fst denote focal mean and focal standard deviation respectively.

LOC	PROJID	Ref.	2008_tc3_fcm	2009_tc2_fcm	2009_ndvi_fcm	aspect fst	sin fcm
14	51-27-14	0.25	-389.25	137.33	0.25	102.04	0.43
19	51-27-19	0.46	-281.29	207.64	0.32	60.25	0.47
29	51-27-29	0.85	24.69	152.90	0.35	25.70	-0.90
57	51-27-57	0.41	193.36	457.29	0.37	10.43	0.96
81	51-27-81	0.39	-7.17	143.30	0.29	78.04	-0.75
117	51-27-117	0.71	79.65	16.40	0.33	11.98	-0.74
123	51-27-123	0.81	88.73	443.06	0.38	37.02	0.72
132	51-27-132	0.38	-864.81	-85.41	0.09	21.89	-0.62
146	51-27-146	0.71	-93.02	444.54	0.37	22.56	0.92
181	51-27-181	0.53	-59.52	199.34	0.33	10.38	0.70
311	51-27-311	0.57	-186.33	547.25	0.45	13.48	0.96
237	51-51-237	0.32	-338.58	337.74	0.38	153.65	0.12
243	51-51-243	0.56	-172.57	444.76	0.37	89.80	-0.25

252	51-51-252	0.11	-206.96	237.65	0.25	9.78	-0.97
260	51-51-260	0.90	61.18	268.87	0.36	18.45	-0.88
272	51-51-272	0.75	-27.42	99.23	0.34	22.10	-0.83
293	51-51-293	0.63	58.93	382.92	0.40	137.07	0.28
329	51-51-329	0.82	209.58	135.48	0.33	135.84	-0.08
333	51-51-333	0.67	-249.36	282.58	0.32	7.90	0.80
334	51-51-334	0.74	118.18	17.70	0.28	8.04	-0.78
336	51-51-336	0.27	-434.51	1.85	0.20	22.37	-0.27
337	51-51-337	0.60	-295.06	393.69	0.38	49.35	0.57
347	51-51-347	0.79	36.55	216.60	0.39	99.45	0.48
359	51-51-359	0.71	92.10	468.23	0.35	28.13	0.84
362	51-51-362	0.70	65.55	86.96	0.29	132.79	0.17
374	51-51-374	0.65	-172.28	279.67	0.34	89.97	-0.01
385	51-51-385	0.62	38.95	412.00	0.37	43.00	-0.56
393	51-51-393	0.12	-112.48	462.81	0.40	26.82	-0.89
415	51-51-415	0.80	74.92	22.46	0.31	22.95	-0.58
427	51-51-427	0.60	70.59	171.85	0.39	104.69	0.17
439	51-51-439	0.92	120.79	308.88	0.37	2.49	-0.84
442	51-51-442	0.09	-588.68	439.26	0.28	25.17	0.18
443	51-51-443	0.58	-38.51	215.05	0.35	136.73	-0.10
447	51-51-447	0.71	167.94	405.12	0.35	25.66	0.87
466	51-51-466	0.42	-247.97	475.47	0.37	21.43	-0.78
469	51-51-469	0.30	78.76	213.55	0.28	5.25	-0.61
493	51-51-493	0.48	-15.03	462.51	0.48	69.28	0.50

543	51-51-543	0.57	218.74	304.48	0.33	110.69	0.33
284	51-167-284	0.54	144.20	220.48	0.38	16.02	-0.96
291	51-167-291	0.37	173.97	340.54	0.33	44.40	-0.29
297	51-167-297	0.52	177.29	250.37	0.36	23.46	-0.86
303	51-167-303	1.00	140.74	262.67	0.37	12.69	0.72
361	51-167-361	0.31	-385.70	95.72	0.24	18.45	-0.51
403	51-167-403	0.77	200.23	387.62	0.48	162.42	0.07
458	51-167-458	0.90	93.54	394.24	0.51	9.07	-0.84
472	51-167-472	1.00	208.84	391.74	0.38	35.80	-0.20
476	51-167-476	0.33	-20.36	397.21	0.35	80.56	-0.28
511	51-167-511	0.33	-78.45	323.55	0.38	106.22	-0.35
519	51-167-519	0.42	-327.67	292.89	0.33	7.78	0.91
327	51-195-327	0.44	-1602.61	-197.95	0.12	31.56	0.75
352	51-195-352	0.55	0.45	475.53	0.46	73.72	-0.36
371	51-195-371	0.42	-134.17	178.17	0.35	37.77	-0.78
386	51-195-386	0.35	-35.94	454.58	0.38	27.55	-0.67
428	51-195-428	0.65	138.00	285.02	0.37	103.85	0.37
433	51-195-433	0.73	35.33	243.07	0.37	95.24	0.59
436	51-195-436	0.10	-372.82	404.85	0.33	15.82	0.53
479	51-195-479	0.83	40.73	115.56	0.25	13.37	0.82
482	51-195-482	0.65	-281.06	450.22	0.38	94.75	-0.30
490	51-195-490	0.90	125.72	262.93	0.46	103.90	0.43
494	51-195-494	0.72	56.06	231.92	0.48	4.33	-0.75
497	51-195-497	0.52	1.02	334.63	0.33	125.80	0.34

501	51-195-501	0.70	-16.49	394.73	0.36	103.36	-0.33
509	51-195-509	0.70	135.21	694.55	0.61	15.24	-0.55
524	51-195-524	0.69	-161.59	204.92	0.28	108.35	-0.36
528	51-195-528	0.91	214.45	215.67	0.41	27.95	0.52
533	51-195-533	0.79	159.92	71.08	0.32	5.99	-0.53
539	51-195-539	0.97	264.24	371.17	0.42	98.39	-0.05
561	51-195-561	0.81	-199.11	125.16	0.30	21.07	-0.91
578	51-195-578	0.90	155.04	707.71	0.48	13.49	-0.09
584	51-195-584	0.66	171.89	399.09	0.52	11.30	-0.96
587	51-195-587	0.82	173.76	218.71	0.40	7.01	-0.97
592	51-195-592	0.92	304.23	1172.12	0.70	28.40	0.09
615	51-195-615	0.61	-111.83	336.52	0.32	5.50	0.03
623	51-195-623	0.09	-1244.06	164.53	0.25	65.39	0.36
631	51-195-631	0.61	12.11	246.70	0.41	12.28	0.57
635	51-195-635	0.74	-326.79	301.33	0.35	21.34	0.92
637	51-195-637	1.00	119.37	501.13	0.36	13.00	0.72
649	51-195-649	0.88	48.79	305.34	0.45	8.99	0.18
664	51-195-664	0.68	-1187.54	233.54	0.32	68.68	0.24
669	51-195-669	0.84	-23.54	411.94	0.32	28.76	0.36
678	51-195-678	0.72	-709.49	251.47	0.33	74.41	0.29
690	51-195-690	0.70	-31.44	527.24	0.42	10.39	-0.35
705	51-195-705	0.05	-826.11	-228.39	0.10	38.47	-0.38
739	51-195-739	0.76	78.19	369.85	0.33	27.32	0.75
1304	51-27-1304	0.71	-100.24	277.60	0.32	32.12	-0.29

1315	51-27-1315	0.70	48.78	71.81	0.30	22.07	-0.75
1316	51-27-1316	0.50	-97.83	340.29	0.34	22.28	-0.58
1332	51-27-1332	0.52	84.05	272.01	0.34	21.28	-0.60
1337	51-27-1337	0.80	76.74	542.11	0.40	11.37	0.03
1354	51-27-1354	0.67	-39.40	584.31	0.47	14.72	-0.22
1432	51-27-1432	0.60	161.28	405.07	0.33	25.73	-0.67
1449	51-27-1449	0.37	-285.55	290.92	0.32	37.11	-0.79
1617	51-27-1617	0.82	42.34	21.78	0.26	21.58	-0.80
1622	51-27-1622	0.85	21.69	183.58	0.30	29.07	-0.78
1625	51-27-1625	0.50	-500.75	323.11	0.29	5.23	0.53
1626	51-27-1626	0.13	-452.08	148.29	0.26	92.64	-0.11
1627	51-27-1627	0.60	-138.83	232.24	0.32	24.93	-0.74
1657	51-27-1657	0.49	-121.11	388.89	0.35	25.63	0.84
1689	51-27-1689	0.67	-86.73	59.27	0.24	68.76	-0.36
1690	51-27-1690	0.65	-66.75	-19.47	0.23	104.68	-0.37
1701	51-27-1701	0.70	-134.55	77.32	0.34	101.39	0.43
1704	51-27-1704	0.57	-219.37	327.62	0.33	65.71	-0.46
1724	51-27-1724	0.65	-75.56	109.51	0.28	40.74	-0.81
1730	51-27-1730	0.90	222.38	318.38	0.38	83.03	-0.23
1800	51-51-1800	0.83	217.88	104.75	0.34	139.38	-0.13
1805	51-51-1805	0.74	66.93	691.09	0.47	50.75	0.63
1810	51-51-1810	0.82	-32.72	376.90	0.38	24.27	-0.52
1813	51-51-1813	0.84	5.24	599.34	0.38	2.69	0.72
1828	51-51-1828	0.70	14.08	177.99	0.39	92.67	-0.75

1831	51-51-1831	0.37	-343.01	174.58	0.30	24.55	-0.76
1834	51-51-1834	0.76	-156.62	590.70	0.41	15.55	0.84
1836	51-51-1836	0.37	-268.06	457.89	0.36	38.72	-0.71
1892	51-195-1892	0.81	177.46	333.29	0.37	15.85	0.04
1899	51-195-1899	0.63	-171.47	103.10	0.21	64.82	0.44
2215	51-51-2215	0.68	-5.75	310.49	0.34	21.66	0.74
2216	51-51-2216	0.18	189.46	-21.23	0.23	159.88	-0.21
2224	51-51-2224	0.21	-529.58	683.29	0.35	29.69	0.87
2225	51-51-2225	0.80	113.06	276.47	0.36	9.26	-0.98
2229	51-51-2229	0.10	-640.81	546.67	0.37	38.42	-0.05
2231	51-51-2231	0.29	-433.82	90.15	0.25	19.48	-0.16
2236	51-195-2236	0.73	-85.87	259.40	0.39	156.62	-0.28
2239	51-195-2239	0.79	68.31	169.61	0.37	12.13	-0.57
2244	51-195-2244	0.87	61.51	763.26	0.59	18.37	0.85
2251	51-195-2251	0.90	120.34	59.94	0.37	163.47	-0.05
2256	51-195-2256	0.64	-28.51	534.64	0.37	17.46	0.44
2268	51-195-2268	0.61	139.31	267.98	0.35	65.15	0.62
2271	51-195-2271	0.61	-163.57	233.52	0.33	33.19	-0.77
2287	51-195-2287	0.84	191.80	252.27	0.41	6.52	0.46
2291	51-195-2291	0.61	25.04	350.75	0.36	64.59	-0.45
2307	51-195-2307	0.53	-120.35	286.98	0.36	167.48	0.02
2313	51-195-2313	0.71	180.06	379.98	0.37	131.20	0.41
2319	51-195-2319	0.62	90.75	400.25	0.42	13.86	-0.85
2321	51-195-2321	0.49	-308.01	649.17	0.43	30.41	0.22

2330	51-195-2330	0.78	-9.68	10.73	0.25	4.18	-0.80
2342	51-195-2342	0.85	42.89	426.96	0.35	5.92	-0.09
2344	51-195-2344	0.63	-79.72	314.97	0.37	143.71	0.07
2392	51-195-2392	0.75	123.41	349.14	0.36	29.32	-0.36
2636	51-195-2636	0.22	-203.28	173.68	0.35	162.84	0.01
2637	51-195-2637	0.17	-253.05	20.83	0.19	17.29	-0.65
2641	51-195-2641	0.57	9.32	248.05	0.32	58.76	0.03
2646	51-195-2646	0.73	90.53	81.53	0.30	2.80	-0.99
2647	51-195-2647	0.81	-41.79	382.35	0.45	17.25	-0.55
2651	51-195-2651	0.09	-435.38	169.86	0.25	7.04	0.55
2668	51-195-2668	0.47	-161.49	149.07	0.36	109.38	-0.20
2669	51-195-2669	0.84	-46.31	-33.30	0.20	140.38	0.06

Appendix H: Sample points from "Combined" category used to develop model (Chapter 5)

Label (1: mined, 2: mixed, 3: non-mined) shows the landcover type of photo-plot, PROJID is the unique photo-plot identifier, 2008 and 2009 represent the leaf-on and leaf-off scenes of Landsat, tc represents Tasseled cap and ndvi denotes Normalized Difference vegetation Index. Fcm and fst represent focal mean and focal standard deviation respectively.

Label	PROJID	2008 b1 fst	2009 b5 fcm	2008 tc2 fcm	2009 tc2 fcm	2009 tc3 fcm	2008 Ndvi fcm	2008 ndvi fst	2009 ndvi fcm	Cos fcm	Sin fcm	Ref. canopy
1	51-27-4	150.18	1799.44	-30.74	-182.00	-848.32	0.18	0.03	0.10	-0.65	-0.63	0.00
1	51-27-7	124.11	1955.78	1146.19	336.56	-785.52	0.51	0.10	0.29	0.92	-0.39	0.00
1	51-27-15	28.23	313.11	1224.24	18.19	-73.35	0.82	0.01	0.31	0.77	-0.58	0.88
1	51-27-25	34.62	2619.78	2197.05	410.88	-1676.71	0.85	0.01	0.37	-0.86	0.03	0.74
1	51-27-33	33.57	2557.67	2176.00	882.41	-1438.60	0.84	0.01	0.53	-0.48	0.87	0.80
1	51-27-48	25.11	2535.56	1919.65	354.73	-1719.27	0.85	0.01	0.38	-0.23	0.36	0.66
1	51-27-49	30.87	2788.33	2289.17	422.39	-1877.11	0.88	0.01	0.37	-0.58	-0.41	0.76
1	51-27-58	33.54	1755.22	10.31	-138.71	-871.96	0.18	0.01	0.10	-0.95	0.22	0.00
1	51-27-65	21.21	2233.89	2112.43	336.27	-1398.90	0.85	0.01	0.36	-0.81	-0.56	0.85
1	51-27-114	48.74	1595.22	1203.06	89.91	-836.81	0.64	0.07	0.24	0.67	0.36	0.15
1	51-27-139	44.12	810.44	1360.15	-0.57	-175.91	0.74	0.03	0.20	0.34	-0.86	0.48
1	51-27-159	32.05	3813.11	837.33	257.56	-2381.91	0.50	0.04	0.27	-0.94	0.28	0.00
1	51-27-161	10.01	1196.67	1754.22	164.64	-727.08	0.85	0.01	0.38	-0.43	-0.86	0.87
1	51-27-172	39.16	993.22	1962.02	1048.66	-40.55	0.83	0.01	0.68	0.60	0.32	0.83
1	51-27-183	35.03	1954.67	1755.75	263.84	-1113.08	0.80	0.02	0.33	-0.69	-0.71	0.55
1	51-27-194	30.81	2615.44	2053.93	417.25	-1472.49	0.78	0.04	0.34	-0.89	-0.30	0.69

1	51-27-254	28.39	1481.78	2249.33	461.93	-725.92	0.85	0.03	0.47	-0.40	-0.85	0.79
1	51-27-358	63.18	721.56	1318.79	32.34	-339.70	0.68	0.08	0.26	0.27	-0.93	0.03
1	51-51-234	45.69	3408.89	1443.58	327.76	-2206.33	0.68	0.02	0.30	-0.44	0.66	0.07
1	51-51-245	33.18	2526.89	2195.29	693.93	-1376.71	0.83	0.01	0.46	-0.55	0.70	0.78
1	51-51-278	18.12	636.89	1978.26	79.16	-293.08	0.85	0.01	0.32	0.97	0.10	0.75
1	51-51-279	35.60	2235.33	1957.09	765.25	-1139.47	0.78	0.05	0.52	-0.01	0.93	0.42
1	51-51-286	30.45	1380.67	1755.05	354.16	-662.38	0.81	0.02	0.40	0.63	-0.67	0.64
1	51-51-340	23.93	3892.33	1451.39	427.40	-2752.14	0.71	0.02	0.35	-0.53	0.83	0.03
1	51-51-435	56.25	1045.22	1256.60	83.49	-453.81	0.63	0.09	0.25	0.52	-0.83	0.03
1	51-51-508	119.72	3231.56	2088.38	424.69	-1910.57	0.69	0.12	0.30	-0.12	0.97	0.70
1	51-167-418	54.50	3178.22	1732.62	519.60	-1713.92	0.65	0.04	0.32	0.08	0.94	0.00
1	51-167-450	34.21	3351.22	2137.78	764.43	-1963.71	0.80	0.02	0.42	0.14	0.37	0.30
1	51-167-464	29.58	1585.56	1469.57	339.66	-670.83	0.70	0.02	0.30	0.01	-0.99	0.16
1	51-167-523	44.34	1479.89	1890.21	276.07	-778.49	0.79	0.05	0.37	0.22	-0.79	0.59
1	51-167-552	41.67	1966.44	1839.84	428.81	-1029.88	0.73	0.04	0.38	0.46	0.33	0.93
1	51-167-574	32.07	1435.22	1266.03	524.46	-602.12	0.71	0.02	0.48	0.30	0.60	0.70
1	51-167-674	45.17	2881.89	1438.79	500.29	-1634.28	0.65	0.04	0.35	0.20	0.71	0.27
1	51-195-367	51.05	2457.00	991.03	222.39	-1528.74	0.59	0.02	0.30	-0.02	0.16	0.00
1	51-195-383	34.38	2704.22	2793.07	628.01	-1611.45	0.86	0.01	0.43	-0.82	0.50	0.91
1	51-195-394	64.76	1722.33	1713.53	309.49	-754.73	0.77	0.06	0.30	0.83	-0.30	0.28
1	51-195-412	16.12	1783.00	1580.45	376.51	-748.10	0.73	0.04	0.33	0.94	-0.24	0.05
1	51-195-420	32.36	3324.56	2873.06	602.01	-2142.08	0.85	0.01	0.40	-0.65	0.71	0.74
1	51-195-445	18.89	1308.33	1432.73	164.11	-679.68	0.72	0.02	0.29	0.98	-0.22	0.15
1	51-195-453	66.82	1039.89	1313.34	59.92	-611.87	0.69	0.12	0.25	0.03	-0.98	0.13
1	51-195-456	38.83	1757.89	2104.72	539.93	-766.12	0.79	0.03	0.42	0.72	0.48	0.40
1	51-195-460	54.73	296.00	61.80	-84.69	66.75	0.25	0.03	0.09	0.00	0.00	0.00

1	51-195-487	72.93	1849.00	712.80	49.97	-1042.14	0.49	0.07	0.21	0.56	0.74	0.00
1	51-195-504	33.80	1320.44	1880.68	222.04	-721.08	0.80	0.03	0.38	-0.32	-0.89	0.60
1	51-195-506	106.22	3264.22	1062.60	115.63	-2012.15	0.53	0.09	0.22	0.02	0.81	0.00
1	51-195-514	15.06	717.00	1780.35	110.90	-385.49	0.83	0.01	0.35	0.19	-0.92	1.00
1	51-195-521	29.41	917.00	2109.63	324.83	-428.06	0.85	0.01	0.48	0.17	-0.72	0.84
1	51-195-527	25.12	1342.44	1960.60	171.42	-809.08	0.84	0.02	0.35	0.65	0.10	0.71
1	51-195-541	33.24	2588.89	1751.79	365.26	-1539.77	0.74	0.03	0.33	-0.01	0.99	0.14
1	51-195-547	43.80	2074.56	1337.58	497.80	-1097.19	0.68	0.03	0.41	-0.43	0.84	0.40
1	51-195-548	137.17	1447.11	68.15	-206.76	-678.74	0.21	0.05	0.07	-0.61	-0.77	0.00
1	51-195-553	29.74	2097.44	1718.14	516.38	-956.24	0.74	0.04	0.36	0.35	-0.51	0.45
1	51-195-569	74.63	2557.78	1435.93	201.53	-1634.07	0.67	0.08	0.28	-0.47	0.60	0.24
1	51-195-571	24.66	1471.11	1987.79	179.53	-860.94	0.85	0.02	0.32	-0.17	-0.97	0.85
1	51-195-576	37.46	1476.67	1904.24	492.53	-772.51	0.84	0.02	0.50	-0.87	-0.18	0.96
1	51-195-582	160.16	3034.44	1295.76	166.56	-1751.06	0.55	0.13	0.22	-0.09	0.99	0.00
1	51-195-589	28.43	2615.22	2184.53	598.93	-1160.03	0.80	0.01	0.35	0.35	0.90	0.00
1	51-195-598	11.07	3404.56	2921.85	525.43	-2272.11	0.87	0.01	0.38	-0.13	0.90	0.95
1	51-195-608	102.36	1721.22	-203.40	-307.95	-789.32	0.13	0.02	0.07	-0.87	-0.42	0.00
1	51-195-611	121.03	2298.67	-132.36	-235.75	-1117.03	0.14	0.02	0.10	-0.58	0.65	0.00
1	51-195-617	24.06	1647.89	1818.30	378.95	-922.09	0.82	0.01	0.44	0.78	0.45	0.90
1	51-195-629	114.85	717.00	44.42	-95.78	-235.34	0.19	0.02	0.09	0.93	-0.22	0.01
1	51-195-638	17.64	1262.78	2206.20	308.62	-667.12	0.85	0.01	0.42	0.28	-0.03	0.97
1	51-195-639	57.34	2271.33	2348.20	337.55	-1358.15	0.81	0.07	0.34	-0.72	-0.69	0.97
1	51-195-658	26.47	2744.44	1413.40	283.06	-1826.92	0.68	0.03	0.32	-0.14	0.93	0.07
1	51-195-695	65.57	2410.89	854.68	187.79	-1366.02	0.52	0.07	0.25	0.72	0.67	0.00
1	51-27-1296	11.70	947.67	1870.49	267.56	-410.17	0.84	0.02	0.39	0.81	0.57	0.86
1	51-27-1310	32.60	384.00	1330.23	32.80	-126.17	0.81	0.02	0.28	0.61	-0.76	0.64

1	51-27-1333	73.96	2597.67	1756.59	207.08	-1574.36	0.70	0.07	0.27	-0.88	0.23	0.50
1	51-27-1340	48.48	2145.44	1592.06	281.87	-1341.29	0.76	0.04	0.34		-0.61	0.69
1	51-27-1350	52.22	1945.67	1844.77	448.86	-1037.50	0.79	0.04	0.39	-0.32	-0.26	0.79
1	51-27-1352	67.73	1072.00	1248.02	105.73	-436.90	0.71	0.08	0.25	0.51	-0.86	0.18
1	51-27-1421	98.72	1769.11	682.17	124.44	-1027.73	0.48	0.22	0.23	-0.13	0.79	0.14
1	51-27-1431	33.70	2518.00	1981.00	568.07	-1469.05	0.80	0.01	0.42	-0.86	-0.23	0.53
1	51-27-1433	48.20	3160.56	1898.86	317.35	-2103.44	0.76	0.03	0.30	-0.62	0.52	0.48
1	51-27-1450	53.91	1617.56	1932.66	193.75	-967.53	0.80	0.04	0.32	0.15	-0.81	0.57
1	51-27-1594	79.41	2109.67	1447.75	179.00	-1301.03	0.72	0.13	0.29	-0.17	-0.21	0.65
1	51-27-1620	25.53	3418.22	2320.91	427.29	-2241.00	0.83	0.02	0.33	-0.45	0.88	0.84
1	51-27-1638	40.06	521.56	1673.83	39.58	-83.55	0.83	0.02	0.21	0.92	-0.25	0.70
1	51-27-1647	35.56	2220.56	2394.93	336.62	-1415.46	0.85	0.02	0.36	-0.37	0.65	0.83
1	51-27-1655	62.54	2270.22	939.65	-15.01	-1339.01	0.59	0.08	0.23	-0.64	0.74	0.35
1	51-27-1656	32.57	1369.44	1159.36	102.28	-389.73	0.63	0.19	0.24	-0.79	-0.61	0.26
1	51-27-1670	19.46	379.78	1540.05	0.52	-86.80	0.83	0.02	0.22	0.76	-0.41	0.86
1	51-27-1692	99.28	1031.89	1162.05	159.87	-442.51	0.67	0.09	0.32	-0.22	-0.95	0.73
1	51-51-1765	23.63	2052.11	1616.73	275.03	-1136.88	0.76	0.03	0.30	0.64	-0.24	0.23
1	51-51-1771	24.70	2080.78	1465.29	595.63	-1059.14	0.67	0.07	0.43	-0.84	-0.40	0.50
1	51-27-1772	45.80	654.89	1259.35	209.27	-164.08	0.72	0.05	0.40	0.94	-0.19	0.72
1	51-51-1774	52.29	1261.67	1202.37	157.38	-605.51	0.66	0.07	0.26	0.49	-0.28	0.50
1	51-51-1775	43.41	1085.22	1847.20	227.67	-577.73	0.81	0.02	0.37	0.43	0.42	0.75
1	51-51-1781	41.67	1590.67	1532.95	197.02	-867.95	0.71	0.07	0.31	0.32	0.38	0.37
1	51-51-1784	54.51	1271.44	1651.72	212.85	-558.38	0.71	0.06	0.30	0.53	0.08	0.05
1	51-51-1808	43.37	1063.00	1637.99	460.49	-216.66	0.77	0.03	0.38	0.65	-0.76	0.45
1	51-51-1822	18.59	743.56	1646.44	39.39	-419.35	0.84	0.01	0.25	0.42	-0.87	0.91
1	51-51-1849	33.72	1178.67	1756.44	168.97	-676.89	0.84	0.02	0.35	-0.24	-0.84	0.90

1	51-195-1896	69.65	2918.89	1762.95	294.09	-1760.44	0.71	0.06	0.29	0.35	0.42	0.18
1	51-195-1901	28.73	2862.22	2113.96	379.40	-1902.44	0.79	0.02	0.36	0.51	0.80	0.68
1	51-195-1953	20.30	2314.78	1734.43	545.65	-1052.86	0.72	0.02	0.35	-0.77	-0.22	0.00
1	51-51-2217	34.47	2726.44	1700.51	376.99	-1319.77	0.74	0.04	0.27	0.75	0.05	0.06
1	51-51-2219	54.16	1730.11	1388.42	463.28	-653.83	0.60	0.09	0.35	-0.18	0.76	0.05
1	51-51-2226	24.50	2579.67	1448.87	330.54	-1572.15	0.69	0.02	0.32	0.48	0.71	0.05
1	51-195-2230	102.48	1964.33	880.93	252.40	-941.34	0.50	0.10	0.29	-0.39	-0.87	0.09
1	51-195-2234	37.05	1967.89	1770.28	329.80	-1012.26	0.73	0.05	0.32	-0.04	0.50	0.03
1	51-195-2238	18.11	2969.89	2103.80	452.72	-1767.82	0.77	0.06	0.33	-0.86	0.34	0.30
1	51-195-2250	20.29	1471.22	2121.75	313.77	-807.66	0.83	0.02	0.40	0.32	-0.22	0.91
1	51-195-2253	44.67	2015.11	1909.55	392.07	-1055.53	0.82	0.04	0.36	0.37	0.12	0.89
1	51-195-2254	43.64	1639.00	1957.49	328.65	-790.63	0.81	0.02	0.37	-0.31	-0.91	0.58
1	51-195-2266	43.14	645.78	1285.64	249.64	-128.65	0.70	0.06	0.40	0.93	-0.25	0.43
1	51-195-2274	70.94	2188.56	1611.43	418.48	-1133.86	0.66	0.04	0.35	0.39	0.02	0.21
1	51-195-2275	20.31	2633.00	1015.44	246.85	-1561.44	0.59	0.03	0.28	0.98	0.16	0.02
1	51-195-2288	37.69	2606.33	2132.48	416.82	-1437.78	0.77	0.04	0.32	-0.07	0.98	0.29
1	51-195-2290	38.21	2752.78	1925.03	514.99	-1396.54	0.77	0.04	0.33	-0.78	0.59	0.67
1	51-195-2292	49.21	1383.33	1451.53	387.18	-543.31	0.77	0.02	0.34	0.05	-0.94	0.40
1	51-195-2293	48.90	1777.33	1721.08	319.85	-957.34	0.74	0.05	0.34	0.87	0.44	0.42
1	51-195-2296	34.53	2699.78	2038.79	346.49	-1717.60	0.81	0.03	0.34	-0.99	-0.02	0.77
1	51-195-2303	10.51	1005.56	1622.05	315.46	-425.54	0.81	0.02	0.44	0.94	-0.16	0.88
1	51-195-2312	32.08	2087.56	1894.01	355.05	-1244.87	0.81	0.02	0.38	-0.84	-0.51	0.71
1	51-195-2314	29.32	1508.33	1881.63	565.50	-753.62	0.81	0.02	0.52	-0.65	-0.69	0.74
1	51-195-2315	19.58	498.67	1797.38	486.68	-12.90	0.84	0.01	0.64	0.80	-0.60	0.92
1	51-195-2317	26.32	2833.78	2793.99	466.75	-1775.97	0.88	0.01	0.37	0.34	0.76	0.14
1	51-195-2326	32.27	2172.00	1905.96	358.27	-1312.55	0.79	0.04	0.36	0.16	0.98	0.69

1	51-195-2328	67.77	2105.00	680.86	-111.80	-1223.16	0.41	0.06	0.14	-0.70	0.31	0.05
1	51-195-2331	36.97	1695.33	2089.09	381.17	-900.47	0.81	0.03	0.40	-0.66	0.45	0.78
1	51-195-2333	57.08	2138.44	1636.65	238.56	-1337.30	0.78	0.03	0.33	0.34	-0.12	0.78
1	51-195-2334	244.68	1875.22	1150.16	-45.02	-962.39	0.57	0.16	0.18	0.67	-0.72	0.19
1	51-195-2335	83.85	842.00	-174.20	-213.49	-137.15	0.12	0.01	0.06	0.09	0.62	0.00
1	51-195-2336	127.15	2741.33	752.79	158.62	-1573.14	0.41	0.08	0.22	-0.24	0.95	0.00
1	51-195-2337	33.20	1773.00	2348.39	259.17	-1097.92	0.85	0.01	0.35	-0.12	0.55	1.00
1	51-195-2339	54.77	992.00	-79.08	-153.43	-376.29	0.16	0.01	0.10	0.02	-0.94	0.00
1	51-195-2340	57.36	3751.22	857.70	359.56	-2568.74	0.55	0.04	0.32	-0.94	0.30	0.00
1	51-195-2638	66.27	2544.00	1159.31	276.79	-1514.94	0.64	0.08	0.29	-0.10	-0.93	0.00
1	51-195-2639	37.43	1812.22	1182.88	334.48	-888.10	0.66	0.03	0.34	-0.28	-0.95	0.08
1	51-195-2642	27.58	637.22	1578.94	73.15	-281.32	0.80	0.04	0.32	0.21	-0.81	0.54
1	51-195-2643	118.84	3914.44	816.50	138.48	-2563.09	0.45	0.08	0.23	-0.86	0.42	0.02
1	51-195-2644	25.24	2300.44	2204.92	401.28	-1396.72	0.79	0.02	0.37	-0.89	-0.30	0.67
1	51-195-2665	27.32	1476.89	-166.82	-276.35	-469.21	0.13	0.01	0.08	0.52	0.63	0.00
1	51-195-2666	73.85	2424.56	2035.21	407.26	-1436.24	0.78	0.05	0.36	0.45	0.60	0.81
2	51-27-14	82.99	1883.44	932.09	137.33	-1259.17	0.61	0.11	0.25	-0.10	0.43	0.25
2	51-27-19	53.25	1413.44	1469.72	207.64	-674.40	0.70	0.06	0.32	0.25	0.47	0.46
2	51-27-29	32.92	1222.78	1717.29	152.90	-717.01	0.84	0.01	0.35	-0.02	-0.90	0.85
2	51-27-57	14.85	2921.44	2579.45	457.29	-1925.60	0.87	0.00	0.37	-0.20	0.96	0.41
2	51-27-81	29.38	1280.44	1719.83	143.30	-703.23	0.82	0.02	0.29	0.04	-0.75	0.39
2	51-27-117	25.46	252.67	1333.81	16.40	-45.64	0.83	0.01	0.33	0.64	-0.74	0.71
2	51-27-123	26.23	2660.89	2330.11	443.06	-1720.93	0.85	0.03	0.38	-0.39	0.72	0.81
2	51-27-132	90.65	428.44	363.52	-85.41	-135.99	0.35	0.09	0.09	0.69	-0.62	0.38
2	51-27-146	25.22	2770.44	2129.96	444.54	-1746.66	0.82	0.02	0.37	-0.11	0.92	0.71
2	51-27-181	64.75	1404.56	1887.93	199.34	-825.85	0.77	0.09	0.33	0.69	0.70	0.53

2	51-27-311	32.91	2276.44	1887.61	547.25	-1378.00	0.80	0.06	0.45	0.17	0.96	0.57
2	51-51-237	59.06	1857.33	1690.92	337.74	-1021.20	0.78	0.02	0.38	0.86	0.12	0.32
2	51-51-243	23.95	2530.78	1821.77	444.76	-1487.28	0.78	0.02	0.37	0.04	-0.25	0.56
2	51-51-252	33.64	1631.78	1324.35	237.65	-631.42	0.67	0.04	0.25	-0.15	-0.97	0.11
2	51-51-260	29.61	1737.11	2022.86	268.87	-1047.76	0.83	0.05	0.36	-0.35	-0.88	0.90
2	51-51-272	49.20	699.22	1507.96	99.23	-349.14	0.80	0.03	0.34	0.42	-0.83	0.75
2	51-51-293	38.93	1684.11	1994.89	382.92	-921.96	0.83	0.02	0.40	0.76	0.28	0.63
2	51-51-329	29.16	1032.00	1914.82	135.48	-534.21	0.84	0.03	0.33	0.68	-0.08	0.82
2	51-51-333	51.63	3138.67	1597.94	282.58	-2225.00	0.77	0.07	0.32	-0.58	0.80	0.67
2	51-51-334	20.63	397.44	1173.92	17.70	-125.85	0.82	0.05	0.28	0.61	-0.78	0.74
2	51-51-336	106.89	783.67	992.28	1.85	-339.83	0.62	0.17	0.20	0.89	-0.27	0.27
2	51-51-337	45.77	2384.78	1733.07	393.69	-1536.56	0.79	0.04	0.38	-0.36	0.57	0.60
2	51-51-347	25.14	1147.22	1922.93	216.60	-630.96	0.83	0.01	0.39	0.13	0.48	0.79
2	51-51-359	25.31	2553.33	2148.20	468.23	-1464.10	0.84	0.03	0.35	-0.27	0.84	0.71
2	51-51-362	59.53	930.56	1787.57	86.96	-506.93	0.83	0.05	0.29	0.77	0.17	0.70
2	51-51-374	92.59	2052.11	1333.98	279.67	-1273.25	0.71	0.12	0.34	-0.35	-0.01	0.65
2	51-51-385	25.32	2331.44	1920.83	412.00	-1352.41	0.83	0.02	0.37	-0.49	-0.56	0.62
2	51-51-393	49.08	2056.78	1921.21	462.81	-1107.57	0.79	0.03	0.40	-0.05	-0.89	0.12
2	51-51-415	41.45	277.00	1267.49	22.46	-29.29	0.82	0.04	0.31	0.72	-0.58	0.80
2	51-51-427	32.65	565.89	1682.51	171.85	-158.21	0.80	0.04	0.39	0.97	0.17	0.60
2	51-51-439	32.45	1644.33	2091.71	308.88	-892.91	0.84	0.03	0.37	-0.54	-0.84	0.92
2	51-51-442	164.17	2782.33	1697.14	439.26	-1246.11	0.64	0.05	0.28	-0.89	0.18	0.09
2	51-51-443	57.93	894.44	1667.18	215.05	-297.47	0.80	0.03	0.35	0.68	-0.10	0.58
2	51-51-447	30.75	2593.22	2442.28	405.12	-1617.75	0.85	0.01	0.35	0.22	0.87	0.71
2	51-51-466	54.88	2362.33	1899.45	475.47	-1266.34	0.75	0.05	0.37	-0.51	-0.78	0.42
2	51-51-469	109.42	2284.78	1956.26	213.55	-1252.99	0.76	0.13	0.28	-0.79	-0.61	0.30

2	51-51-493	22.81	1489.00	2138.26	462.51	-766.89	0.84	0.01	0.48	0.61	0.50	0.48
2	51-51-543	25.76	1258.11	2091.37	304.48	-545.17	0.84	0.01	0.33	0.89	0.33	0.57
2	51-167-284	26.56	1102.89	1772.52	220.48	-538.15	0.84	0.02	0.38	0.06	-0.96	0.54
2	51-167-291	20.97	2539.44	2193.74	340.54	-1592.86	0.85	0.02	0.33	0.62	-0.29	0.37
2	51-167-297	46.04	1339.44	1927.99	250.37	-672.37	0.82	0.04	0.36	0.16	-0.86	0.52
2	51-167-303	24.30	1414.11	2108.26	262.67	-777.36	0.85	0.02	0.37	0.16	0.72	1.00
2	51-167-361	183.89	2049.67	934.15	95.72	-1039.12	0.50	0.18	0.24	0.25	-0.51	0.31
2	51-167-403	37.82	1132.00	2115.95	387.62	-535.55	0.83	0.04	0.48	0.36	0.07	0.77
2	51-167-458	30.50	1094.44	1729.23	394.24	-484.92	0.84	0.01	0.51	0.08	-0.84	0.90
2	51-167-472	15.81	2220.78	2108.33	391.74	-1333.31	0.85	0.01	0.38	0.52	-0.20	1.00
2	51-167-476	20.42	2331.44	2079.76	397.21	-1381.66	0.81	0.04	0.35	0.91	-0.28	0.33
2	51-167-511	38.18	1706.56	1926.81	323.55	-907.89	0.80	0.05	0.38	0.31	-0.35	0.33
2	51-167-519	79.02	2322.78	1397.73	292.89	-1409.33	0.68	0.09	0.33	0.05	0.91	0.42
2	51-195-327	85.12	1938.11	238.46	-197.95	-1001.92	0.23	0.04	0.12	0.42	0.75	0.44
2	51-195-352	29.97	1964.44	1795.06	475.53	-1133.64	0.82	0.02	0.46	-0.16	-0.36	0.55
2	51-195-371	105.47	987.67	1344.72	178.17	-429.53	0.73	0.09	0.35	-0.17	-0.78	0.42
2	51-195-386	25.19	1714.44	1779.48	454.58	-729.70	0.77	0.02	0.38	-0.59	-0.67	0.35
2	51-195-428	25.49	1509.89	2182.00	285.02	-819.49	0.85	0.02	0.37	0.88	0.37	0.65
2	51-195-433	15.26	1485.89	2214.41	243.07	-899.88	0.85	0.04	0.37	0.60	0.59	0.73
2	51-195-436	81.04	2770.67	1996.53	404.85	-1611.69	0.73	0.06	0.33	-0.81	0.53	0.10
2	51-195-479	32.00	1258.67	2086.86	115.56	-360.09	0.81	0.04	0.25	0.52	0.82	0.83
2	51-195-482	33.31	1910.67	1852.11	450.22	-946.98	0.79	0.02	0.38	-0.10	-0.30	0.65
2	51-195-490	29.35	1009.67	2074.54	262.93	-487.93	0.83	0.01	0.46	0.86	0.43	0.90
2	51-195-494	31.09	543.33	1382.82	231.92	-136.03	0.80	0.02	0.48	0.66	-0.75	0.72
2	51-195-497	61.82	1219.00	1749.20	334.63	-341.97	0.76	0.07	0.33	0.45	0.34	0.52
2	51-195-501	39.74	1719.78	1869.51	394.73	-831.29	0.81	0.05	0.36	0.11	-0.33	0.70

2	51-195-509	37.62	935.67	1611.78	694.55	-195.50	0.78	0.03	0.61	0.79	-0.55	0.70
2	51-195-524	51.75	895.44	1437.89	204.92	-231.04	0.75	0.04	0.28	0.40	-0.36	0.69
2	51-195-528	23.00	1043.56	2011.15	215.67	-580.90	0.85	0.02	0.41	0.72	0.52	0.91
2	51-195-533	16.65	637.22	1653.69	71.08	-311.63	0.85	0.01	0.32	0.84	-0.53	0.79
2	51-195-539	39.44	1488.78	2257.93	371.17	-777.04	0.85	0.01	0.42	0.10	-0.05	0.97
2	51-195-561	409.78	978.44	520.95	125.16	-526.98	0.50	0.10	0.30	0.20	-0.91	0.81
2	51-195-578	20.33	2362.78	2083.87	707.71	-1253.54	0.83	0.03	0.48	-0.97	-0.09	0.90
2	51-195-584	25.66	1040.33	1844.63	399.09	-468.05	0.81	0.03	0.52	0.19	-0.96	0.66
2	51-195-587	42.07	784.11	1876.15	218.71	-270.23	0.84	0.02	0.40	0.22	-0.97	0.82
2	51-195-592	38.21	1152.11	2171.74	1172.12	-158.27	0.83	0.01	0.70	-0.88	0.09	0.92
2	51-195-615	227.51	2912.78	2203.38	336.52	-1846.67	0.75	0.19	0.32	-0.99	0.03	0.61
2	51-195-623	96.89	2256.56	754.18	164.53	-1305.31	0.41	0.07	0.25	-0.28	0.36	0.09
2	51-195-631	10.34	1225.22	1920.39	246.70	-682.77	0.83	0.02	0.41	0.79	0.57	0.61
2	51-195-635	159.93	1858.00	1577.30	301.33	-1039.24	0.70	0.16	0.35	0.13	0.92	0.74
2	51-195-637	20.75	3102.22	2470.94	501.13	-1966.79	0.86	0.01	0.36	-0.66	0.72	1.00
2	51-195-649	20.67	1375.67	1877.50	305.34	-741.48	0.83	0.02	0.45	0.97	0.18	0.88
2	51-195-664	81.95	2132.56	1130.55	233.54	-1301.67	0.56	0.09	0.32	-0.54	0.24	0.68
2	51-195-669	49.53	3513.89	2175.96	411.94	-2299.02	0.80	0.03	0.32	-0.80	0.36	0.84
2	51-195-678	57.30	2234.11	1455.62	251.47	-1430.99	0.66	0.11	0.33	0.05	0.29	0.72
2	51-195-690	59.44	2672.78	2196.60	527.24	-1647.21	0.78	0.06	0.42	-0.92	-0.35	0.70
2	51-195-705	53.15	2365.33	-84.59	-228.39	-1080.15	0.16	0.02	0.10	-0.70	-0.38	0.05
2	51-195-739	36.08	2948.11	2446.02	369.85	-1902.28	0.84	0.02	0.33	-0.48	0.75	0.76
2	51-27-1304	91.77	1799.11	1771.48	277.60	-981.90	0.75	0.10	0.32	-0.80	-0.29	0.71
2	51-27-1315	35.32	832.33	1571.90	71.81	-445.17	0.81	0.02	0.30	0.55	-0.75	0.70
2	51-27-1316	66.94	2132.11	1937.67	340.29	-1280.07	0.79	0.07	0.34	-0.73	-0.58	0.50
2	51-27-1332	24.64	1808.33	2048.12	272.01	-1037.72	0.84	0.02	0.34	-0.72	-0.60	0.52

2	51-27-1337	37.93	2265.22	2157.64	542.11	-1210.27	0.83	0.04	0.40	-0.98	0.03	0.80
2	51-27-1354	10.65	2149.78	2006.00	584.31	-1181.52	0.83	0.02	0.47	-0.94	-0.22	0.67
2	51-27-1432	66.77	2003.33	2036.27	405.07	-887.89	0.81	0.02	0.33	-0.61	-0.67	0.60
2	51-27-1449	69.14	1942.56	1760.85	290.92	-1078.67	0.74	0.05	0.32	0.12	-0.79	0.37
2	51-27-1617	56.68	667.89	1233.59	21.78	-296.41	0.75	0.05	0.26	0.47	-0.80	0.82
2	51-27-1622	43.29	1671.00	1584.92	183.58	-1025.23	0.75	0.08	0.30	-0.40	-0.78	0.85
2	51-27-1625	62.07	3502.22	1550.76	323.11	-2345.41	0.68	0.02	0.29	-0.84	0.53	0.50
2	51-27-1626	56.52	2074.56	1250.11	148.29	-1312.61	0.65	0.06	0.26	-0.31	-0.11	0.13
2	51-27-1627	50.78	1927.89	1702.51	232.24	-1170.55	0.79	0.04	0.32	-0.53	-0.74	0.60
2	51-27-1657	42.83	2681.33	1635.93	388.89	-1784.00	0.76	0.12	0.35	-0.34	0.84	0.49
2	51-27-1689	36.00	641.22	1195.70	59.27	-269.83	0.75	0.04	0.24	0.42	-0.36	0.67
2	51-27-1690	43.60	264.33	1159.11	-19.47	13.87	0.73	0.06	0.23	0.86	-0.37	0.65
2	51-27-1701	23.88	592.44	1617.36	77.32	-284.91	0.78	0.03	0.34	0.86	0.43	0.70
2	51-27-1704	35.58	2034.78	1692.81	327.62	-1186.45	0.74	0.07	0.33	-0.11	-0.46	0.57
2	51-27-1724	46.30	1080.78	1510.15	109.51	-600.27	0.81	0.06	0.28	0.08	-0.81	0.65
2	51-27-1730	11.07	1803.89	2082.56	318.38	-1053.01	0.85	0.01	0.38	-0.17	-0.23	0.90
2	51-51-1800	31.89	712.22	1909.94	104.75	-377.98	0.85	0.01	0.34	0.83	-0.13	0.83
2	51-51-1805	13.92	1808.11	2099.60	691.09	-708.78	0.81	0.01	0.47	0.27	0.63	0.74
2	51-51-1810	94.74	2030.00	1918.06	376.90	-1175.13	0.75	0.11	0.38	-0.75	-0.52	0.82
2	51-51-1813	25.47	3573.22	2236.32	599.34	-2330.79	0.85	0.02	0.38	-0.69	0.72	0.84
2	51-51-1828	37.44	610.33	1468.89	177.99	-168.48	0.81	0.03	0.39	0.50	-0.75	0.70
2	51-51-1831	140.25	1542.00	1122.85	174.58	-858.15	0.64	0.16	0.30	-0.49	-0.76	0.37
2	51-51-1834	75.91	2056.67	2082.14	590.70	-940.14	0.75	0.11	0.41	-0.47	0.84	0.76
2	51-51-1836	95.20	1945.67	1887.63	457.89	-882.10	0.73	0.11	0.36	-0.35	-0.71	0.37
2	51-195-1892	24.91	2256.11	2320.79	333.29	-1423.36	0.85	0.03	0.37	-0.96	0.04	0.81
2	51-195-1899	49.18	1844.22	1341.12	103.10	-960.00	0.68	0.19	0.21	-0.28	0.44	0.63

2	51-51-2215	31.98	2296.89	2305.92	310.49	-1433.11	0.83	0.03	0.34	0.56	0.74	0.68
2	51-51-2216	11.07	263.00	1713.09	-21.23	6.36	0.83	0.01	0.23	0.95	-0.21	0.18
2	51-51-2224	38.03	2492.11	1622.80	683.29	-823.40	0.67	0.02	0.35	0.08	0.87	0.21
2	51-51-2225	20.18	1773.22	2085.09	276.47	-1041.72	0.87	0.01	0.36	-0.06	-0.98	0.80
2	51-51-2229	30.43	2290.00	1747.22	546.67	-1099.51	0.72	0.02	0.37	-0.79	-0.05	0.10
2	51-51-2231	64.85	2007.56	859.70	90.15	-1370.44	0.59	0.17	0.25	-0.93	-0.16	0.29
2	51-195-2236	51.73	1485.22	1860.15	259.40	-878.42	0.83	0.04	0.39	0.82	-0.28	0.73
2	51-195-2239	32.57	1205.67	1935.64	169.61	-727.19	0.83	0.03	0.37	0.80	-0.57	0.79
2	51-195-2244	21.67	1347.11	1855.66	763.26	-452.40	0.81	0.02	0.59	0.41	0.85	0.87
2	51-195-2251	43.42	236.00	1281.47	59.94	15.99	0.78	0.02	0.37	0.99	-0.05	0.90
2	51-195-2256	68.01	1804.11	1882.96	534.64	-641.13	0.78	0.04	0.37	0.85	0.44	0.64
2	51-195-2268	33.82	1675.33	2033.36	267.98	-985.99	0.84	0.02	0.35	0.19	0.62	0.61
2	51-195-2271	84.68	1621.89	1557.18	233.52	-887.92	0.72	0.12	0.33	-0.36	-0.77	0.61
2	51-195-2287	36.66	1467.00	2251.08	252.27	-928.18	0.85	0.02	0.41	0.88	0.46	0.84
2	51-195-2291	52.36	1853.44	1960.55	350.75	-993.89	0.83	0.03	0.36	-0.10	-0.45	0.61
2	51-195-2307	37.09	1701.11	1988.95	286.98	-929.82	0.81	0.02	0.36	1.00	0.02	0.53
2	51-195-2313	20.44	2163.00	2221.49	379.98	-1312.26	0.85	0.02	0.37	0.61	0.41	0.71
2	51-195-2319	19.98	1581.11	2038.67	400.25	-764.19	0.82	0.01	0.42	-0.46	-0.85	0.62
2	51-195-2321	67.24	2692.67	1977.20	649.17	-1564.26	0.77	0.08	0.43	-0.84	0.22	0.49
2	51-195-2330	77.89	508.00	1451.38	10.73	-190.72	0.76	0.10	0.25	0.59	-0.80	0.78
2	51-195-2342	28.47	2618.11	2301.44	426.96	-1567.16	0.83	0.03	0.35	-0.99	-0.09	0.85
2	51-195-2344	44.80	1571.33	1519.64	314.97	-825.77	0.78	0.02	0.37	0.88	0.07	0.63
2	51-195-2392	30.87	2139.89	2113.62	349.14	-1276.10	0.83	0.02	0.36	-0.80	-0.36	0.75
2	51-195-2636	48.88	1280.44	1650.74	173.68	-713.93	0.77	0.06	0.35	0.97	0.01	0.22
2	51-195-2637	352.60	1245.00	270.53	20.83	-567.02	0.26	0.03	0.19	0.70	-0.65	0.17
2	51-195-2641	58.61	1987.11	2000.41	248.05	-1215.31	0.79	0.08	0.32	-0.72	0.03	0.57

2	51-195-2646	24.10	734.78	1427.25	81.53	-353.17	0.80	0.02	0.30	-0.12	-0.99	0.73
2	51-195-2647	20.10	1662.11	1872.08	382.35	-960.21	0.83	0.02	0.45	-0.78	-0.55	0.81
2	51-195-2651	76.01	1999.78	1231.49	169.86	-1036.76	0.64	0.07	0.25	0.82	0.55	0.09
2	51-195-2668	171.21	1036.33	1522.21	149.07	-551.81	0.70	0.14	0.36	0.96	-0.20	0.47
2	51-195-2669	187.37	405.78	1282.97	-33.30	-137.49	0.65	0.17	0.20	0.81	0.06	0.84
3	51-27-1	20.13	3368.89	1931.29	477.24	-2310.12	0.85	0.01	0.38	-0.93	0.04	0.91
3	51-27-2	18.38	939.00	1665.96	86.55	-504.07	0.84	0.02	0.28	0.24	-0.72	0.61
3	51-27-3	19.18	1045.33	1642.44	148.14	-535.81	0.84	0.01	0.32	-0.28	-0.80	0.80
3	51-27-5	19.99	3573.44	2257.52	406.76	-2506.47	0.85	0.02	0.34	-0.48	0.86	0.43
3	51-27-6	20.09	348.56	1437.56	-6.58	-108.58	0.83	0.01	0.26	0.92	-0.33	0.78
3	51-27-8	35.14	2925.67	1748.44	345.42	-2006.98	0.83	0.01	0.35	-0.96	-0.06	0.80
3	51-27-9	29.41	2052.11	1822.03	268.86	-1328.42	0.83	0.01	0.36	0.32	0.90	0.72
3	51-27-10	12.75	3479.89	2164.55	500.13	-2374.86	0.85	0.01	0.38	-0.14	0.98	0.94
3	51-27-11	30.11	304.22	1399.90	13.58	-24.95	0.83	0.02	0.23	0.10	-0.97	0.38
3	51-27-12	15.21	2784.11	2133.93	408.99	-1840.39	0.85	0.01	0.37	0.05	0.98	0.97
3	51-27-13	31.93	867.78	1616.22	98.48	-477.24	0.84	0.02	0.32	0.76	-0.61	0.67
3	51-27-16	11.07	2278.56	2138.17	372.02	-1431.82	0.86	0.01	0.36	-0.36	-0.23	0.84
3	51-27-17	14.03	2149.78	1872.09	328.35	-1310.51	0.83	0.02	0.35	-0.24	0.42	0.80
3	51-27-18	20.25	2167.56	2099.05	320.78	-1320.39	0.86	0.01	0.35	-0.45	0.32	0.96
3	51-27-20	28.64	566.11	1669.44	72.44	-219.06	0.85	0.01	0.32	0.22	-0.95	0.72
3	51-27-21	35.03	424.22	1358.47	-0.78	-148.34	0.82	0.02	0.23	0.72	-0.64	0.83
3	51-27-22	18.38	2265.44	1820.52	326.83	-1454.64	0.85	0.02	0.36	-0.05	0.80	0.74
3	51-27-23	23.73	206.78	1376.06	-21.97	2.63	0.82	0.01	0.20	0.95	-0.22	0.82
3	51-27-24	50.57	3103.22	1970.43	558.49	-1919.12	0.78	0.07	0.38	-0.92	0.18	0.76
3	51-27-26	32.71	969.89	1842.28	153.72	-539.58	0.85	0.02	0.36	0.99	-0.10	0.84
3	51-27-27	29.55	2655.44	2221.87	507.31	-1716.89	0.86	0.02	0.43	-0.48	0.85	0.85

3	51-27-28	14.30	3675.00	2367.70	596.58	-2496.50	0.86	0.01	0.39	-0.73	0.65	0.49
3	51-27-30	25.52	1453.33	1747.30	209.31	-888.83	0.84	0.01	0.38	0.67	0.72	0.89
3	51-27-31	18.19	2961.33	2373.25	430.37	-2014.80	0.87	0.01	0.37	-0.66	0.28	0.76
3	51-27-32	25.31	1613.00	2048.41	271.33	-972.87	0.85	0.01	0.39	-0.15	-0.36	0.81
3	51-27-34	49.75	1067.33	1671.43	122.41	-560.02	0.79	0.03	0.31	0.53	0.01	0.50
3	51-27-35	17.29	3657.78	2609.80	566.04	-2465.85	0.88	0.01	0.37	-0.81	0.57	0.79
3	51-27-36	15.18	3209.67	2362.28	557.97	-2121.96	0.87	0.01	0.40	-0.69	0.59	0.90
3	51-27-37	25.77	859.00	1443.15	113.06	-447.73	0.82	0.02	0.36	-0.08	-0.90	0.90
3	51-27-38	19.24	2593.22	1894.69	368.23	-1600.56	0.81	0.03	0.34	-0.92	-0.08	0.66
3	51-27-39	19.41	1174.00	1826.81	155.56	-699.47	0.86	0.01	0.33	0.46	0.03	0.75
3	51-27-40	28.44	1657.56	2049.05	306.70	-921.67	0.85	0.01	0.36	0.01	-0.20	0.50
3	51-27-41	23.63	1320.11	1914.78	250.34	-730.92	0.85	0.01	0.38	-0.57	-0.69	0.85
3	51-27-42	34.31	468.56	1589.68	121.71	-117.02	0.83	0.01	0.38	0.92	-0.23	0.65
3	51-27-43	49.43	1835.00	1558.77	287.35	-1023.77	0.79	0.05	0.34	-0.46	-0.78	0.74
3	51-27-44	26.91	1236.11	1975.63	155.69	-682.04	0.84	0.01	0.31	0.72	0.43	0.93
3	51-27-45	24.36	2903.56	2309.78	439.18	-1955.91	0.85	0.01	0.39	-0.03	0.99	0.46
3	51-27-46	18.54	3010.11	2465.29	451.89	-2004.01	0.88	0.01	0.37	-0.67	0.63	0.73
3	51-27-47	18.77	805.67	1741.98	94.93	-409.20	0.85	0.01	0.32	0.74	-0.54	0.77
3	51-27-50	73.00	1670.56	1683.96	265.35	-874.67	0.75	0.08	0.33	-0.03	-0.27	0.64
3	51-27-51	10.59	1675.00	1624.48	264.59	-1016.83	0.83	0.01	0.37	-0.45	-0.84	0.91
3	51-27-52	26.44	2597.67	2100.95	402.86	-1714.22	0.86	0.01	0.38	-0.60	0.19	0.68
3	51-27-53	28.97	2805.89	2396.11	525.63	-1759.43	0.85	0.02	0.39	-0.88	0.34	0.96
3	51-27-55	13.53	699.22	1515.57	94.66	-354.31	0.82	0.01	0.34	0.05	-0.98	0.22
3	51-27-56	53.00	912.22	1513.22	174.54	-352.84	0.77	0.06	0.34	0.96	0.17	0.67
3	51-27-59	35.04	3018.78	1998.96	369.48	-2073.36	0.83	0.01	0.37	-0.50	0.81	0.80
3	51-27-60	32.55	1967.89	2052.71	500.48	-1050.90	0.82	0.03	0.42	-0.60	-0.04	0.72

3	51-27-61	56.30	1874.89	1863.35	715.16	-855.94	0.77	0.05	0.49	-0.32	-0.64	0.57
3	51-27-62	15.34	2109.89	1882.50	223.70	-1456.35	0.84	0.01	0.33	-0.21	-0.22	0.80
3	51-27-63	23.34	947.78	1549.94	138.99	-485.03	0.83	0.02	0.34	-0.01	-0.99	0.91
3	51-27-64	19.59	2500.00	2187.52	367.60	-1585.86	0.86	0.01	0.35	-0.80	-0.12	0.89
3	51-27-66	21.85	872.22	1937.54	155.49	-436.48	0.86	0.01	0.36	0.05	-0.82	0.55
3	51-27-67	14.85	1107.22	1819.88	170.77	-656.21	0.84	0.01	0.37	0.59	-0.12	0.75
3	51-27-68	18.64	1156.33	1976.12	171.78	-660.93	0.85	0.01	0.34	0.91	0.27	0.88
3	51-27-69	20.41	1936.89	1801.31	316.31	-1177.52	0.84	0.01	0.38	-0.64	-0.76	0.90
3	51-27-70	36.93	650.56	1406.33	90.66	-315.02	0.80	0.04	0.35	0.15	-0.97	0.07
3	51-27-71	16.42	490.67	1554.05	32.88	-212.75	0.83	0.01	0.29	0.84	-0.31	0.69
3	51-27-72	17.68	1737.44	2156.19	341.55	-1025.27	0.86	0.01	0.38	0.03	0.54	0.67
3	51-27-73	20.10	3533.11	2381.06	517.02	-2405.42	0.85	0.01	0.37	-0.87	0.39	0.74
3	51-27-74	20.51	548.33	1586.57	86.25	-223.35	0.83	0.02	0.36	0.93	0.17	0.86
3	51-27-75	28.79	1786.11	1842.62	343.93	-990.21	0.82	0.04	0.38	-0.74	-0.64	0.39
3	51-27-76	20.72	628.22	1551.45	204.78	-159.24	0.82	0.01	0.41	-0.18	-0.88	0.82
3	51-27-77	23.59	952.11	1629.63	168.46	-469.46	0.83	0.01	0.38	0.04	-0.96	0.52
3	51-27-78	15.03	2176.22	2280.81	458.13	-1210.03	0.86	0.01	0.37	-0.52	0.62	0.74
3	51-27-79	13.32	401.67	1558.48	27.64	-112.52	0.84	0.01	0.27	0.60	-0.75	0.55
3	51-27-80	15.54	2167.78	2065.25	357.19	-1361.61	0.85	0.01	0.38	0.36	0.93	0.00
3	51-27-82	65.64	2096.67	2020.40	295.53	-1171.03	0.81	0.07	0.32	0.44	0.89	0.95
3	51-27-83	22.98	1772.56	1886.39	304.39	-1067.59	0.84	0.01	0.39	-0.67	-0.64	0.90
3	51-27-84	61.66	1883.67	1954.83	314.50	-1027.38	0.79	0.05	0.35	-0.41	-0.50	0.48
3	51-27-85	22.74	517.11	1588.21	68.33	-205.79	0.83	0.02	0.31	0.90	0.11	0.67
3	51-27-86	22.59	881.22	1699.57	190.82	-447.99	0.84	0.01	0.42	-0.25	-0.96	0.96
3	51-27-87	17.04	3032.11	2201.38	539.33	-1941.74	0.85	0.01	0.39	-0.79	0.44	0.89
3	51-27-88	19.75	2805.89	2525.79	465.86	-1784.10	0.87	0.01	0.37	-0.08	0.97	0.62

3	51-27-89	13.55	2030.00	2012.60	336.20	-1246.44	0.85	0.01	0.36	-0.91	-0.31	0.54
3	51-27-90	16.55	863.33	1662.21	131.95	-470.15	0.84	0.01	0.36	0.83	0.43	0.82
3	51-27-91	19.75	464.11	1440.32	70.95	-186.48	0.83	0.03	0.36	0.77	-0.42	0.94
3	51-27-92	18.09	3307.22	1957.37	434.94	-2261.42	0.84	0.01	0.37	-0.69	0.47	0.93
3	51-27-93	39.63	2242.78	1933.02	330.88	-1448.93	0.79	0.05	0.39	-0.12	0.31	0.38
3	51-27-94	38.60	2629.00	2277.19	426.94	-1723.43	0.84	0.02	0.40	0.27	0.87	0.59
3	51-27-95	21.94	330.89	1333.20	46.03	-54.40	0.83	0.02	0.32	0.25	-0.91	0.25
3	51-27-96	18.80	3019.44	2504.79	462.39	-2037.87	0.87	0.00	0.37	-0.33	0.93	0.03
3	51-27-97	14.98	1675.78	1960.44	423.25	-951.58	0.84	0.01	0.45	-0.60	-0.46	0.93
3	51-27-98	22.48	699.11	1619.57	123.42	-329.52	0.84	0.02	0.37	0.01	-0.92	0.94
3	51-27-99	24.87	1622.11	1916.25	280.03	-940.60	0.85	0.01	0.36	-0.71	-0.64	0.88
3	51-27-100	22.17	2358.11	2299.43	365.63	-1463.65	0.86	0.01	0.35	-0.85	-0.39	0.86
3	51-27-101	11.74	2584.44	2404.42	472.09	-1590.06	0.87	0.01	0.38	-0.88	0.32	0.76
3	51-27-102	15.26	455.00	1584.53	81.83	-151.27	0.84	0.01	0.35	0.67	-0.61	0.93
3	51-27-103	28.71	1897.22	2002.90	310.24	-1100.94	0.84	0.02	0.35	-0.45	-0.31	0.96
3	51-27-104	19.85	721.33	1533.34	84.63	-380.64	0.82	0.01	0.32	0.86	0.49	0.89
3	51-27-105	80.87	1404.44	1634.79	227.10	-795.96	0.78	0.09	0.35	0.35	-0.70	0.67
3	51-27-106	22.48	290.78	1302.66	10.26	-62.05	0.82	0.03	0.23	0.50	-0.86	0.83
3	51-27-107	17.44	1657.22	1651.10	292.70	-929.84	0.82	0.01	0.36	-0.40	-0.89	0.68
3	51-27-108	17.76	379.44	1567.04	83.42	-89.71	0.85	0.01	0.32	0.85	-0.16	0.86
3	51-27-109	23.06	2850.11	2042.41	501.27	-1864.48	0.84	0.01	0.41	-0.12	0.98	0.89
3	51-27-110	25.01	730.11	1482.55	121.86	-329.97	0.82	0.01	0.34	0.96	0.03	0.70
3	51-27-111	47.01	3213.89	2177.90	502.96	-2060.50	0.82	0.04	0.36	-0.37	0.83	0.83
3	51-27-112	22.48	357.67	1457.91	33.97	-81.23	0.82	0.02	0.28	0.95	-0.18	0.81
3	51-27-115	17.99	1657.44	1944.52	175.47	-1098.25	0.85	0.02	0.34	0.42	0.89	0.77
3	51-27-116	24.50	801.44	1717.91	127.77	-388.17	0.84	0.01	0.37	0.15	-0.86	0.53

3	51-27-119	58.24	1393.22	1527.13	268.26	-746.93	0.78	0.07	0.40	-0.17	-0.88	0.49
3	51-27-121	31.34	717.22	1774.01	133.07	-295.78	0.86	0.01	0.35	0.97	-0.21	0.62
3	51-27-122	19.02	104.56	1115.83	-28.97	101.52	0.80	0.02	0.17	0.48	-0.79	0.14
3	51-27-124	19.61	1923.44	2154.02	756.87	-931.62	0.84	0.02	0.56	-0.54	0.68	0.95
3	51-27-125	21.22	2211.78	1819.21	375.13	-1366.28	0.84	0.01	0.39	-0.83	-0.46	0.87
3	51-27-126	23.53	1560.11	1880.50	291.96	-880.56	0.83	0.02	0.40	0.11	-0.32	0.29
3	51-27-127	18.09	1103.33	1533.13	360.39	-510.41	0.80	0.02	0.50	-0.45	-0.34	0.74
3	51-27-128	35.11	495.33	1666.52	38.27	-167.82	0.84	0.01	0.29	0.41	-0.77	0.84
3	51-27-129	19.80	939.44	1718.85	163.74	-432.61	0.83	0.02	0.32	0.77	0.45	0.72
3	51-27-131	22.14	814.67	1901.54	126.46	-419.35	0.85	0.01	0.36	0.89	0.37	0.77
3	51-27-133	17.10	330.56	1597.31	37.93	-13.77	0.84	0.02	0.29	0.95	-0.14	0.73
3	51-27-134	18.20	239.33	1143.19	-15.16	14.28	0.82	0.02	0.25	0.50	-0.70	0.89
3	51-27-136	27.37	1227.00	1987.98	158.88	-677.99	0.84	0.03	0.32	0.74	0.14	0.70
3	51-27-137	20.67	543.89	1419.11	46.49	-257.44	0.81	0.01	0.33	0.21	-0.95	0.89
3	51-27-138	10.27	1715.22	2026.33	327.17	-959.63	0.85	0.01	0.38	-0.81	-0.54	0.88
3	51-27-141	28.20	2575.56	2217.75	396.07	-1620.22	0.86	0.01	0.36	-0.79	-0.50	0.53
3	51-27-142	18.19	885.67	1727.09	155.06	-466.82	0.84	0.01	0.39	0.89	0.37	0.62
3	51-27-143	17.18	1329.11	1940.49	212.17	-743.15	0.85	0.01	0.36	-0.36	-0.84	0.62
3	51-27-144	17.52	565.89	1606.74	120.93	-222.46	0.83	0.01	0.40	0.97	0.11	0.77
3	51-27-145	26.20	2633.56	2145.59	407.09	-1700.51	0.85	0.01	0.38	-0.12	0.94	0.92
3	51-27-148	27.06	2061.00	2047.58	315.41	-1272.12	0.85	0.01	0.36	-0.09	0.85	0.71
3	51-27-149	43.27	2886.00	1983.35	490.64	-1829.22	0.80	0.04	0.39	-0.96	0.01	0.61
3	51-27-150	30.65	1733.22	2210.99	298.38	-1002.09	0.86	0.01	0.37	-0.49	-0.76	0.80
3	51-27-151	23.15	2327.00	2206.59	537.07	-1328.45	0.86	0.01	0.42	-0.84	-0.21	0.84
3	51-27-153	28.65	2500.22	2021.27	411.35	-1560.32	0.82	0.02	0.37	-0.94	0.11	0.77
3	51-27-154	10.01	2633.44	2079.12	396.39	-1731.76	0.83	0.02	0.39	0.17	0.97	0.69

3	51-27-155	45.28	273.11	1272.33	-23.79	-13.93	0.76	0.08	0.23	0.82	-0.55	0.49
3	51-27-156	15.33	601.44	1388.26	51.76	-266.08	0.81	0.02	0.34	0.21	-0.93	0.88
3	51-27-158	14.62	3018.89	2313.59	463.88	-2029.72	0.86	0.01	0.39	-0.81	-0.30	0.79
3	51-27-163	22.15	2078.56	1885.59	391.93	-1198.72	0.79	0.07	0.37	-0.25	0.72	0.61
3	51-27-164	121.99	1808.11	1422.62	781.87	-752.70	0.69	0.13	0.52	-0.52	0.45	0.23
3	51-27-166	20.30	508.22	1473.43	20.35	-209.94	0.82	0.02	0.28	0.96	0.28	0.67
3	51-27-167	60.10	2047.56	1866.99	689.18	-898.82	0.76	0.04	0.45	0.23	0.89	0.28
3	51-27-168	23.42	1045.44	1880.33	178.81	-535.26	0.83	0.02	0.35	0.55	-0.62	0.78
3	51-27-169	26.33	3546.67	2209.17	626.25	-2341.15	0.84	0.02	0.41	-0.60	0.79	0.90
3	51-27-171	68.34	1280.33	1680.48	152.87	-728.96	0.77	0.05	0.28	0.39	-0.34	0.22
3	51-27-173	21.32	3218.78	2297.95	518.66	-2084.99	0.86	0.01	0.37	-0.92	0.22	0.89
3	51-27-175	21.05	259.78	1355.81	20.48	26.64	0.82	0.03	0.28	0.72	-0.66	0.61
3	51-27-176	29.09	3338.22	2193.48	563.96	-2260.76	0.85	0.01	0.41	-0.44	0.84	0.86
3	51-27-178	24.09	517.11	1788.51	37.98	-182.49	0.85	0.01	0.27	0.99	0.12	0.82
3	51-27-180	24.60	2979.33	2445.65	604.55	-1846.67	0.87	0.01	0.41	-0.71	0.64	0.90
3	51-27-185	17.74	881.00	1957.40	120.88	-443.10	0.85	0.02	0.33	0.86	0.47	0.91
3	51-27-186	112.53	3083.89	1899.60	461.49	-2082.25	0.79	0.09	0.38	-0.26	0.95	0.33
3	51-27-188	44.73	3378.67	2087.40	552.92	-2318.00	0.82	0.07	0.41	-0.57	0.78	0.87
3	51-27-189	60.40	797.00	1461.89	131.46	-388.59	0.77	0.05	0.36	0.93	0.26	0.90
3	51-27-191	26.72	2340.44	2197.31	328.03	-1534.59	0.85	0.01	0.37	0.54	0.59	0.82
3	51-27-193	28.06	2744.22	2509.52	401.98	-1752.38	0.87	0.01	0.36	-0.23	0.97	0.95
3	51-27-196	31.39	1107.33	1749.77	114.05	-648.11	0.85	0.01	0.30	-0.03	-0.40	0.92
3	51-27-198	20.52	2698.11	2172.08	527.20	-1672.93	0.84	0.03	0.39	-0.92	0.08	0.83
3	51-27-199	17.99	2615.67	2095.35	375.84	-1757.80	0.85	0.02	0.38	-0.46	-0.07	0.88
3	51-27-201	22.47	459.44	1559.24	28.97	-143.93	0.83	0.01	0.29	0.37	-0.93	0.90
3	51-27-203	30.71	1271.67	1792.92	169.71	-694.21	0.82	0.03	0.31	0.07	-0.94	0.53

3	51-27-204	40.50	1613.22	1761.78	326.31	-893.19	0.83	0.02	0.38	-0.15	-0.64	0.93
3	51-27-206	26.23	1875.67	1870.67	590.91	-944.50	0.83	0.01	0.49	-0.96	-0.25	0.79
3	51-27-209	22.64	2362.78	1808.91	410.95	-1055.22	0.72	0.02	0.30	0.84	0.26	0.08
3	51-27-211	14.31	1151.56	1945.65	180.76	-656.65	0.85	0.02	0.38	0.52	0.15	0.81
3	51-27-214	33.89	610.33	1686.85	68.75	-275.38	0.83	0.02	0.29	0.63	-0.67	0.77
3	51-27-216	22.18	2757.56	2378.89	454.36	-1778.93	0.87	0.01	0.39	-0.77	-0.03	0.75
3	51-27-217	35.08	2473.78	2099.10	662.25	-1424.22	0.84	0.01	0.47	-0.72	0.54	0.75
3	51-27-219	57.28	1271.33	1880.09	226.76	-599.80	0.81	0.02	0.32	0.06	-0.44	0.78
3	51-27-221	23.33	962.00	2171.43	217.90	-381.74	0.87	0.01	0.34	0.21	-0.68	0.70
3	51-27-222	23.95	1701.67	1815.12	235.97	-979.27	0.84	0.01	0.34	-0.64	-0.74	0.95
3	51-27-224	29.77	2395.22	1990.43	789.21	-1264.21	0.84	0.02	0.52	-0.53	-0.10	0.81
3	51-27-228	70.87	841.33	1338.01	73.43	-460.60	0.76	0.10	0.31	0.21	-0.94	0.62
3	51-27-230	17.77	290.89	1454.97	11.39	-12.93	0.81	0.01	0.27	0.93	-0.34	0.74
3	51-27-233	34.97	2065.56	1724.23	584.55	-1091.42	0.77	0.03	0.47	-0.45	0.30	0.46
3	51-27-235	24.57	885.33	1652.04	118.53	-464.00	0.83	0.02	0.32	0.31	-0.93	0.24
3	51-27-238	24.41	752.56	1446.03	99.44	-350.57	0.84	0.01	0.32	0.27	-0.91	0.80
3	51-27-244	20.59	1555.56	1902.72	251.06	-861.71	0.83	0.02	0.34	0.71	0.49	0.81
3	51-27-248	18.86	2212.00	2150.18	338.88	-1438.35	0.85	0.01	0.39	0.33	0.88	0.92
3	51-27-250	67.54	1741.89	1838.77	305.18	-952.63	0.80	0.06	0.37	-0.17	-0.28	0.59
3	51-27-259	20.91	2708.56	2350.13	728.64	-1548.71	0.85	0.01	0.46	-0.49	0.71	0.81
3	51-27-265	18.51	836.89	1913.53	81.51	-432.13	0.85	0.01	0.32	0.98	0.11	0.75
3	51-27-271	22.09	2180.78	2155.33	391.38	-1176.58	0.82	0.03	0.34	-0.41	0.41	0.74
3	51-27-275	19.22	1578.89	1913.64	352.54	-879.88	0.84	0.01	0.42	-0.24	-0.77	0.91
3	51-27-277	44.18	2300.67	2216.92	316.65	-1355.67	0.83	0.04	0.33	0.27	0.95	0.55
3	51-27-281	135.10	1282.22	1357.50	334.66	-497.32	0.67	0.07	0.37	-0.33	0.10	0.30
3	51-27-288	22.81	139.67	1375.87	1.31	70.61	0.84	0.02	0.30	0.47	-0.87	0.89

3	51-27-294	14.56	1067.44	1885.74	226.62	-539.98	0.85	0.01	0.38	-0.19	-0.96	0.97
3	51-27-300	30.62	1014.22	1695.50	184.95	-530.78	0.83	0.01	0.37	0.66	0.54	0.93
3	51-27-304	14.21	504.00	1501.37	35.65	-191.85	0.84	0.02	0.31	0.48	-0.84	0.92
3	51-27-307	25.76	1764.33	2243.72	319.15	-986.37	0.85	0.01	0.37	-0.60	-0.47	0.84
3	51-27-325	24.11	734.89	1782.45	126.64	-328.57	0.85	0.01	0.36	0.71	-0.21	0.85
3	51-27-332	21.92	1514.89	2182.13	327.20	-797.61	0.86	0.02	0.38	-0.58	-0.66	0.87
3	51-27-343	30.62	1762.22	2277.90	332.74	-1022.68	0.86	0.01	0.37	-0.31	-0.37	0.82
3	51-27-350	14.97	2447.56	2640.85	609.95	-1435.94	0.87	0.01	0.41	-0.25	0.92	0.70
3	51-27-376	53.15	1965.00	2079.72	260.93	-1155.48	0.78	0.03	0.32	0.83	0.39	0.10
3	51-51-113	22.73	1153.89	1910.08	298.69	-616.32	0.85	0.01	0.46	0.60	0.02	0.94
3	51-51-118	33.23	1759.33	1875.30	258.84	-1127.95	0.85	0.02	0.37	0.57	0.58	0.84
3	51-51-130	18.09	1963.44	2371.41	458.57	-1131.83	0.86	0.01	0.43	-0.22	0.97	0.92
3	51-51-135	23.59	228.78	1344.76	-20.76	-3.93	0.82	0.02	0.21	0.79	-0.54	0.93
3	51-51-140	28.53	1879.22	1997.25	323.40	-1108.11	0.84	0.01	0.38	-0.69	-0.10	0.93
3	51-51-147	22.08	3112.11	2143.37	524.57	-1992.19	0.84	0.01	0.37	-0.80	0.28	0.90
3	51-51-152	21.09	1116.33	1542.43	326.09	-559.09	0.82	0.02	0.48	-0.73	-0.38	0.90
3	51-51-157	14.33	260.00	1488.86	-24.83	-46.40	0.83	0.01	0.20	0.85	-0.52	0.88
3	51-51-160	18.76	1715.89	2185.44	533.14	-933.55	0.85	0.01	0.51	-0.78	-0.17	0.95
3	51-51-162	30.62	1719.22	2114.62	214.25	-1091.28	0.84	0.01	0.34	0.36	0.83	0.84
3	51-51-165	38.72	2380.67	1864.71	471.21	-1227.36	0.76	0.05	0.34	0.37	-0.29	0.31
3	51-51-170	23.53	3490.33	1963.65	801.85	-2218.57	0.83	0.02	0.47	-0.60	0.51	0.72
3	51-51-174	21.22	379.78	1105.28	78.49	-72.92	0.76	0.02	0.37	0.96	0.08	0.96
3	51-51-177	12.63	2677.44	2438.25	537.35	-1682.40	0.86	0.01	0.42	-0.12	0.99	0.96
3	51-51-179	18.29	1267.00	1871.31	147.00	-749.81	0.84	0.01	0.32	-0.18	-0.63	0.90
3	51-51-182	19.19	1874.44	1909.58	668.75	-937.46	0.82	0.01	0.53	-0.83	0.45	0.88
3	51-51-184	82.46	3154.33	1875.49	663.68	-1915.12	0.74	0.06	0.42	-0.25	0.93	0.42

3	51-51-187	16.42	130.33	77.06	-379.74	268.85	0.48	0.08	-0.42	0.00	0.00	0.00
3	51-51-190	16.82	1356.11	2231.26	360.62	-730.40	0.86	0.02	0.45	-0.59	0.42	0.97
3	51-51-192	14.85	1272.67	1485.88	215.47	-716.28	0.81	0.01	0.40	0.72	-0.26	0.87
3	51-51-195	17.17	2338.11	2063.66	562.58	-1382.11	0.83	0.00	0.44	-0.88	0.46	0.96
3	51-51-197	35.96	1590.00	1531.85	362.55	-933.67	0.80	0.03	0.46	-0.13	0.55	0.73
3	51-51-200	106.31	2583.33	1526.10	614.29	-1171.03	0.62	0.09	0.37	-0.50	0.54	0.21
3	51-51-202	50.29	2374.11	1562.78	364.86	-1453.64	0.74	0.06	0.36	-0.73	-0.54	0.39
3	51-51-205	46.10	2289.00	1531.89	710.24	-896.14	0.68	0.06	0.40	-0.92	-0.28	0.25
3	51-51-207	21.59	1479.89	1818.27	331.27	-826.55	0.83	0.01	0.42	-0.69	-0.34	0.87
3	51-51-208	22.81	1564.33	2401.42	560.69	-809.64	0.86	0.00	0.53	0.25	0.91	0.99
3	51-51-210	12.62	2438.22	2048.08	391.08	-1513.00	0.85	0.00	0.37	-0.81	0.09	0.90
3	51-51-212	32.35	410.78	1334.26	93.50	-100.95	0.80	0.01	0.37	0.98	0.12	0.91
3	51-51-213	17.81	979.33	1549.33	147.94	-541.64	0.82	0.01	0.37	0.03	-0.97	0.94
3	51-51-215	15.07	1023.33	1530.56	160.28	-536.16	0.82	0.02	0.36	-0.58	-0.71	0.95
3	51-51-218	23.84	2935.22	2019.54	465.98	-1926.53	0.85	0.01	0.40	-0.89	0.34	0.90
3	51-51-220	11.07	1253.89	1809.38	176.70	-736.07	0.85	0.01	0.36	0.61	-0.06	0.91
3	51-51-223	21.21	890.22	1401.56	104.96	-426.11	0.81	0.04	0.32	0.13	-0.97	0.87
3	51-51-225	34.05	1972.33	1740.96	404.74	-1099.74	0.79	0.05	0.39	-0.15	0.59	0.52
3	51-51-226	9.85	1200.78	1924.90	314.23	-652.64	0.85	0.01	0.47	-0.62	-0.56	0.98
3	51-51-229	11.39	1617.67	1850.57	421.48	-861.41	0.83	0.01	0.47	0.52	0.47	0.83
3	51-51-231	14.57	468.33	1492.32	193.81	-85.31	0.82	0.01	0.48	0.61	-0.52	0.90
3	51-51-232	20.51	836.89	1555.23	170.61	-380.84	0.82	0.02	0.36	0.62	-0.76	0.93
3	51-51-236	23.26	1431.78	1721.24	229.43	-821.61	0.83	0.01	0.37	-0.48	-0.86	0.94
3	51-51-239	15.26	1063.22	1830.02	148.61	-600.08	0.84	0.01	0.36	0.78	0.37	0.84
3	51-51-242	45.27	1688.11	1795.15	356.24	-973.68	0.81	0.01	0.42	0.48	0.80	0.78
3	51-51-246	10.92	1486.00	1857.05	472.86	-724.96	0.83	0.02	0.48	-0.20	-0.44	0.90

3	51-51-249	29.44	1466.78	1717.05	209.42	-882.69	0.82	0.01	0.38	0.08	0.67	0.80
3	51-51-251	14.85	1750.44	1895.90	212.49	-1142.09	0.85	0.02	0.37	0.56	0.81	0.73
3	51-51-255	18.40	2407.00	1924.76	497.68	-1486.56	0.84	0.01	0.45	-0.94	-0.19	0.83
3	51-51-257	58.52	1098.67	1416.47	181.72	-518.68	0.73	0.09	0.35	0.10	-0.88	0.58
3	51-51-258	12.62	672.44	1298.62	91.90	-257.83	0.80	0.02	0.31	0.41	-0.88	0.83
3	51-51-263	12.62	1574.44	1834.67	600.78	-793.22	0.83	0.01	0.55	-0.55	-0.16	0.78
3	51-51-264	25.47	1864.56	1936.03	283.97	-1146.93	0.84	0.01	0.36	0.59	0.65	0.74
3	51-51-266	20.00	446.22	1536.90	23.99	-151.74	0.83	0.01	0.24	0.64	-0.70	0.86
3	51-51-269	17.61	734.89	1498.69	80.44	-360.71	0.82	0.02	0.29	0.96	-0.14	0.75
3	51-51-270	11.32	2339.11	2128.11	513.82	-1424.67	0.85	0.01	0.43	0.08	0.98	0.83
3	51-51-273	20.91	1672.33	1755.16	234.08	-1012.09	0.82	0.02	0.36	0.80	0.45	0.71
3	51-51-276	41.13	2562.11	2091.14	452.72	-1601.63	0.82	0.03	0.40	0.47	0.85	0.71
3	51-51-282	12.49	3010.22	1944.56	503.73	-1997.60	0.83	0.04	0.41	-0.23	0.97	0.61
3	51-51-285	26.04	2090.22	2200.46	443.34	-1242.47	0.86	0.00	0.43	-0.75	-0.39	0.86
3	51-51-289	28.82	437.22	1478.51	40.85	-152.15	0.83	0.02	0.32	0.23	-0.95	0.87
3	51-51-292	42.18	1679.44	1720.49	404.72	-754.72	0.76	0.03	0.37	-0.20	-0.13	0.44
3	51-51-295	20.17	1710.78	2018.18	261.66	-1050.77	0.84	0.01	0.36	0.71	0.50	0.75
3	51-51-298	27.09	2345.00	2198.37	346.76	-1451.37	0.86	0.01	0.34	0.32	0.89	0.71
3	51-51-299	31.59	1528.78	1623.65	292.90	-808.99	0.83	0.01	0.36	0.57	-0.36	0.84
3	51-51-301	24.91	1098.44	2034.98	148.78	-668.95	0.86	0.01	0.38	0.71	-0.21	0.72
3	51-51-302	72.58	1888.89	1732.61	288.66	-1116.87	0.79	0.06	0.37	-0.38	-0.92	0.83
3	51-51-305	19.39	1719.56	1996.16	332.28	-821.63	0.81	0.03	0.35	0.29	-0.30	0.20
3	51-51-308	18.53	1599.67	2137.37	399.51	-804.68	0.87	0.01	0.38	-0.16	-0.58	0.84
3	51-51-309	18.52	2193.00	1860.19	283.56	-1423.44	0.84	0.01	0.37	-0.13	-0.09	0.70
3	51-51-312	15.89	978.78	1764.48	152.73	-503.82	0.85	0.01	0.34	0.17	-0.76	0.76
3	51-51-315	27.52	1249.67	1426.80	260.18	-662.39	0.78	0.03	0.41	-0.34	-0.86	0.72

3	51-51-316	27.54	2187.33	1978.92	346.81	-1364.90	0.83	0.01	0.37	0.04	0.94	0.70
3	51-51-319	33.47	1151.78	1579.40	220.43	-619.90	0.84	0.01	0.40	-0.26	-0.96	0.56
3	51-51-322	19.59	316.89	1614.02	8.73	-87.97	0.83	0.01	0.25	0.90	-0.37	0.89
3	51-51-323	20.21	3489.56	2380.11	540.24	-2328.58	0.87	0.01	0.38	-0.26	0.86	0.81
3	51-51-326	31.32	1133.89	1965.49	194.76	-649.48	0.85	0.01	0.38	0.58	-0.54	0.88
3	51-51-330	16.06	872.44	1916.50	190.46	-404.86	0.86	0.01	0.39	0.28	-0.92	0.93
3	51-51-341	14.00	1089.78	1751.61	135.21	-616.52	0.84	0.01	0.35	0.83	0.20	0.94
3	51-51-344	20.10	3235.89	2188.71	474.14	-2169.50	0.85	0.01	0.37	-0.66	0.48	0.86
3	51-51-348	14.62	996.67	1635.30	287.62	-511.83	0.83	0.02	0.48	0.51	-0.55	0.97
3	51-51-351	22.43	2739.67	2123.38	519.08	-1725.14	0.84	0.01	0.42	0.21	0.97	0.85
3	51-51-354	10.18	2598.00	2363.40	510.84	-1592.95	0.87	0.01	0.40	-0.69	-0.34	0.88
3	51-51-363	23.04	2673.89	2533.69	634.21	-1572.05	0.87	0.01	0.42	-0.56	0.72	0.90
3	51-51-366	35.78	2322.67	1970.55	421.71	-1387.80	0.84	0.02	0.37	-0.15	0.30	0.83
3	51-51-370	24.80	419.33	1521.09	91.86	-116.56	0.83	0.01	0.36	0.35	-0.94	0.89
3	51-51-373	18.23	801.33	1887.27	86.42	-449.16	0.85	0.01	0.32	0.94	0.14	0.80
3	51-51-377	23.54	1391.11	2061.77	208.92	-815.28	0.85	0.01	0.35	0.26	0.59	0.80
3	51-51-380	17.42	1595.33	2304.56	250.36	-881.00	0.85	0.02	0.32	-0.85	-0.14	0.84
3	51-51-381	20.42	770.33	1449.85	381.75	-253.95	0.81	0.02	0.57	-0.35	-0.91	0.92
3	51-51-388	26.84	1883.56	2296.49	302.73	-1149.70	0.86	0.01	0.37	-0.40	-0.86	0.90
3	51-51-389	17.95	796.78	1587.25	327.88	-235.17	0.83	0.01	0.47	1.00	0.03	0.81
3	51-51-397	20.51	3166.22	2319.50	792.33	-1920.18	0.85	0.01	0.46	-0.99	0.06	0.82
3	51-51-400	16.72	2553.33	2598.05	461.08	-1591.77	0.88	0.01	0.39	-0.10	0.34	0.76
3	51-51-404	17.23	1143.00	2116.61	321.39	-535.48	0.85	0.02	0.44	-0.35	-0.86	0.89
3	51-51-407	28.58	978.78	1866.39	132.03	-552.12	0.84	0.01	0.33	-0.18	-0.76	0.87
3	51-51-408	33.20	2340.22	2089.97	836.54	-1205.18	0.83	0.04	0.51	-0.84	-0.27	0.87
3	51-51-411	27.87	2939.22	2104.08	468.74	-1912.72	0.85	0.01	0.38	-0.90	-0.24	0.94

3	51-51-414	31.97	2185.11	2472.64	351.76	-1343.97	0.87	0.01	0.36	0.47	0.84	0.90
3	51-51-419	25.67	2385.11	2460.66	684.97	-1356.16	0.86	0.01	0.47	-0.14	0.97	0.74
3	51-51-423	24.55	1001.67	1746.96	296.59	-507.75	0.84	0.01	0.50	-0.12	-0.99	0.95
3	51-51-431	36.57	1981.22	1882.64	430.72	-979.70	0.77	0.03	0.36	0.81	0.23	0.24
3	51-51-451	9.11	1089.78	2103.14	182.34	-618.00	0.86	0.01	0.37	0.83	0.14	0.92
3	51-51-455	21.75	934.22	2107.10	154.49	-506.64	0.86	0.01	0.37	0.80	0.03	0.90
3	51-51-459	6.76	997.33	1855.43	308.03	-494.72	0.84	0.01	0.43	-0.25	-0.80	0.93
3	51-51-462	30.33	1546.56	2102.63	289.21	-845.18	0.86	0.01	0.37	-0.03	-0.15	0.88
3	51-51-473	32.25	1231.56	2089.72	536.58	-553.63	0.85	0.01	0.54	0.63	0.75	0.67
3	51-51-481	17.66	783.67	1802.87	133.55	-378.81	0.85	0.01	0.33	0.07	-0.97	0.92
3	51-51-489	41.09	1967.78	1993.12	336.78	-1093.34	0.81	0.06	0.34	0.27	0.87	0.90
3	51-51-500	15.07	2974.56	2529.28	663.46	-1780.01	0.86	0.01	0.41	-0.78	0.60	0.76
3	51-51-516	19.61	3152.00	2763.21	516.22	-2061.29	0.88	0.01	0.37	-0.25	0.92	0.83
3	51-195-283	11.07	2319.78	2413.78	576.87	-1333.88	0.86	0.01	0.44	-0.70	0.49	0.78
3	51-195-290	21.64	2174.11	2046.94	486.01	-1296.12	0.85	0.01	0.43	-0.74	0.47	0.99
3	51-195-296	25.48	788.22	1786.51	170.67	-345.08	0.83	0.01	0.36	0.62	0.00	0.91
3	51-195-306	32.12	2584.22	2407.76	907.52	-1346.12	0.83	0.01	0.52	-0.87	0.41	0.81
3	51-195-313	16.69	2398.78	1945.47	547.18	-1454.60	0.84	0.01	0.45	0.15	0.67	0.70
3	51-195-320	38.29	1606.78	1703.70	579.91	-779.31	0.81	0.03	0.51	-0.88	-0.35	0.79
3	51-195-331	21.88	2030.89	2235.72	656.37	-1060.15	0.85	0.01	0.48	-0.95	0.22	0.96
3	51-195-338	146.94	2585.67	1468.29	683.86	-1400.95	0.64	0.13	0.45	-0.34	0.88	0.38
3	51-195-357	16.14	1346.67	2052.28	321.79	-715.39	0.85	0.01	0.45	0.47	0.54	0.96
3	51-195-360	24.28	1449.22	2058.16	198.08	-890.77	0.85	0.01	0.36	0.88	0.45	0.78
3	51-195-364	26.30	561.56	613.51	-65.56	-60.84	0.67	0.13	0.10	0.73	-0.36	0.48
3	51-195-378	45.08	1160.56	1784.84	252.60	-598.22	0.83	0.02	0.39	-0.41	-0.80	0.64
3	51-195-391	19.23	2117.44	2026.53	454.71	-1279.26	0.85	0.01	0.43	0.03	0.91	0.91

3	51-195-398	25.62	1580.78	2124.13	314.02	-885.94	0.85	0.01	0.39	-0.15	0.32	0.95
3	51-195-401	26.95	748.11	1459.95	209.42	-258.34	0.81	0.02	0.41	-0.06	-0.72	0.84
3	51-195-405	25.50	1527.22	1886.11	287.42	-861.15	0.83	0.01	0.39	-0.70	-0.71	0.94
3	51-195-417	32.82	1801.89	2036.70	425.50	-1030.33	0.84	0.01	0.44	-0.42	-0.61	0.83
3	51-195-425	26.07	1029.44	1787.84	197.23	-570.90	0.84	0.01	0.40	-0.23	-0.82	0.79
3	51-195-440	26.73	2788.56	2469.20	498.02	-1740.73	0.86	0.03	0.39	-0.28	0.94	0.85
3	51-195-448	75.23	1735.22	1648.56	331.01	-877.82	0.73	0.05	0.37	0.88	0.46	0.14
3	51-195-463	17.90	1396.00	1992.13	349.55	-743.11	0.85	0.01	0.43	-0.45	-0.88	0.98
3	51-195-467	38.12	1720.56	2157.51	856.07	-665.54	0.80	0.05	0.54	-0.65	0.03	0.71
3	51-195-470	65.43	2225.11	2027.52	496.65	-1279.31	0.80	0.06	0.44	0.37	0.86	0.82
3	51-195-474	17.34	1400.44	2077.50	228.09	-776.88	0.85	0.02	0.36	-0.44	-0.88	0.99
3	51-195-477	18.74	1320.44	2291.17	351.32	-687.52	0.86	0.01	0.44	0.25	-0.62	0.90
3	51-195-485	17.33	1098.56	2115.37	254.94	-546.19	0.86	0.01	0.41	0.22	-0.92	0.99
3	51-195-512	20.36	1905.89	2148.17	387.77	-1048.04	0.86	0.02	0.38	0.36	0.43	0.93
3	51-195-517	121.47	1954.67	1310.26	495.45	-753.18	0.60	0.09	0.37	0.28	-0.71	0.11
3	51-195-520	26.74	1728.56	2045.87	319.32	-1043.71	0.85	0.02	0.40	0.56	-0.53	0.91
3	51-195-531	22.70	1422.67	2303.65	300.92	-800.39	0.85	0.01	0.40	0.83	0.54	0.94
3	51-195-535	250.92	1849.44	1664.06	366.76	-962.62	0.66	0.07	0.36	-0.11	0.55	0.91
3	51-195-536	17.76	1219.00	2077.48	345.12	-664.47	0.85	0.01	0.49	-0.58	-0.77	0.93
3	51-195-544	22.97	3003.44	2352.14	445.03	-1931.69	0.83	0.02	0.35	-0.67	0.16	0.48
3	51-195-550	13.98	2247.33	2229.47	336.00	-1401.63	0.86	0.01	0.36	-0.85	-0.41	0.97
3	51-195-551	122.56	2064.00	1547.56	493.03	-903.45	0.64	0.08	0.38	0.04	0.88	0.25
3	51-195-555	10.34	2903.33	2375.80	546.29	-1734.56	0.86	0.01	0.36	-0.70	0.37	0.81
3	51-195-556	21.29	1867.67	2435.32	736.38	-935.25	0.86	0.01	0.56	-0.73	0.65	0.92
3	51-195-559	52.67	2744.56	1817.47	767.01	-984.92	0.67	0.02	0.36	0.72	0.58	0.01
3	51-195-563	25.32	1333.56	1933.84	208.25	-813.14	0.85	0.01	0.39	-0.30	-0.94	0.97

3	51-195-564	21.72	1051.67	1855.57	345.74	-486.21	0.83	0.02	0.49	-0.43	-0.74	0.96
3	51-195-567	109.17	1861.67	1699.72	461.45	-806.93	0.72	0.10	0.38	0.54	0.79	0.47
3	51-195-572	76.75	2280.33	1957.22	909.93	-853.72	0.74	0.04	0.47	-0.27	0.93	0.09
3	51-195-575	22.55	2327.00	2593.84	491.59	-1367.31	0.87	0.01	0.39	-0.76	0.18	0.88
3	51-195-579	31.79	1751.89	2483.77	342.37	-1004.15	0.87	0.01	0.39	0.31	0.94	0.90
3	51-195-583	28.14	2385.67	2151.16	478.29	-1385.36	0.84	0.03	0.39	-0.89	0.31	0.88
3	51-195-586	14.44	677.22	1615.27	43.21	-308.95	0.84	0.02	0.27	0.93	-0.36	0.98
3	51-195-591	17.46	3049.89	2723.06	506.44	-1937.54	0.88	0.00	0.37	-0.76	0.37	0.90
3	51-195-595	27.15	1356.33	1976.42	476.94	-615.65	0.84	0.01	0.47	-0.33	-0.89	0.80
3	51-195-596	18.07	1275.89	1797.31	198.73	-732.85	0.82	0.01	0.38	-0.42	-0.90	1.00
3	51-195-599	14.68	855.11	1929.37	119.34	-466.01	0.85	0.01	0.37	0.92	-0.05	0.90
3	51-195-602	50.10	3048.78	2296.49	502.58	-1894.28	0.82	0.04	0.36	-0.60	-0.01	0.56
3	51-195-603	26.00	361.89	1465.36	14.14	-148.51	0.82	0.01	0.31	0.79	-0.60	0.90
3	51-195-605	24.39	1991.22	1948.76	307.93	-1192.12	0.85	0.01	0.37	-0.78	-0.55	0.87
3	51-195-610	88.79	1989.78	1376.02	491.31	-913.27	0.69	0.06	0.38	-0.10	0.02	0.43
3	51-195-613	27.92	2455.11	2227.47	400.06	-1521.70	0.84	0.01	0.38	-0.82	0.16	0.93
3	51-195-614	6.95	1055.00	2068.64	215.02	-567.72	0.85	0.01	0.40	-0.72	-0.44	1.00
3	51-195-618	35.88	1304.11	1936.32	470.28	-629.53	0.83	0.01	0.51	-0.45	-0.72	0.88
3	51-195-621	24.39	783.67	1960.92	116.92	-394.06	0.85	0.01	0.35	0.99	-0.04	0.84
3	51-195-624	9.33	1737.44	1933.92	457.39	-915.42	0.84	0.01	0.46	0.19	0.71	0.92
3	51-195-625	16.42	1775.67	2145.36	432.15	-953.71	0.85	0.01	0.43	-0.83	-0.49	0.95
3	51-195-628	25.75	1192.00	2055.53	231.23	-590.33	0.85	0.01	0.35	0.83	-0.16	0.92
3	51-195-634	113.33	2332.11	1761.94	427.22	-1242.07	0.73	0.08	0.36	-0.03	0.29	0.47
3	51-195-641	30.19	1768.44	2288.49	317.31	-1015.91	0.86	0.01	0.38	0.91	0.18	1.00
3	51-195-642	19.99	1040.44	1490.13	361.76	-532.15	0.84	0.02	0.54	0.93	0.23	0.94
3	51-195-645	23.50	2132.00	2232.60	480.99	-1206.10	0.86	0.02	0.40	0.08	0.35	0.96

3	51-195-646	15.14	2123.22	2545.08	350.54	-1335.76	0.87	0.01	0.38	-0.08	0.75	0.90
3	51-195-648	20.26	2221.00	2060.92	513.23	-1216.57	0.82	0.02	0.39	0.23	0.39	0.85
3	51-195-651	19.71	2451.56	2257.70	482.80	-1393.77	0.84	0.01	0.36	0.03	0.95	0.89
3	51-195-654	19.19	2075.78	2006.72	344.85	-1201.07	0.85	0.02	0.34	0.23	-0.80	0.86
3	51-195-655	10.51	1503.44	2240.04	260.91	-937.71	0.86	0.01	0.40	-0.37	-0.04	0.91
3	51-195-657	25.93	1240.33	2107.41	497.99	-556.44	0.84	0.01	0.52	-0.17	-0.97	0.85
3	51-195-660	33.17	1295.89	1478.49	145.08	-744.87	0.77	0.05	0.26	0.00	0.00	0.70
3	51-195-663	346.52	2868.22	1904.89	605.18	-1759.54	0.61	0.09	0.41	-0.50	0.80	0.98
3	51-195-667	13.47	2296.11	2771.88	408.87	-1332.62	0.86	0.01	0.35	-0.17	0.98	0.86
3	51-195-670	17.91	730.44	2024.23	268.16	-306.40	0.85	0.02	0.50	0.85	-0.34	0.93
3	51-195-672	13.97	1936.89	2521.37	504.95	-1009.61	0.86	0.01	0.42	-0.42	0.40	0.99
3	51-195-673	27.28	2127.56	2195.05	477.91	-1223.01	0.84	0.01	0.42	-0.59	-0.49	0.91
3	51-195-675	50.22	2815.22	1750.60	645.03	-1279.01	0.70	0.03	0.36	-0.51	-0.21	0.06
3	51-195-677	24.62	1497.67	2439.58	493.67	-706.49	0.87	0.01	0.45	0.10	0.62	0.92
3	51-195-680	13.21	735.00	1889.03	153.28	-323.51	0.85	0.01	0.39	0.90	-0.44	0.88
3	51-195-682	25.69	410.33	1908.64	44.83	-147.71	0.85	0.02	0.35	0.87	-0.42	1.00
3	51-195-685	22.48	3147.67	2923.24	501.45	-2059.44	0.87	0.01	0.37	-0.95	-0.05	0.87
3	51-195-687	31.18	3143.67	2470.94	523.94	-2064.86	0.87	0.01	0.39	-0.97	0.20	0.92
3	51-195-692	26.56	4278.33	1634.26	685.85	-2558.60	0.64	0.03	0.34	-0.78	0.07	0.10
3	51-195-696	28.70	261.67	1851.40	33.36	-48.91	0.86	0.01	0.29	0.40	-0.85	0.83
3	51-195-698	25.86	695.00	1538.34	88.95	-322.40	0.82	0.02	0.35	-0.05	-0.99	0.90
3	51-195-700	17.00	1937.44	2250.69	798.11	-931.60	0.85	0.01	0.54	-0.75	0.62	0.83
3	51-195-702	78.65	1717.89	290.39	-78.13	-899.60	0.33	0.08	0.20	0.86	-0.47	0.10
3	51-195-707	24.65	1225.22	1774.72	184.59	-644.97	0.84	0.01	0.33	0.64	-0.65	1.00
3	51-195-710	14.00	654.78	1663.78	103.86	-310.11	0.83	0.01	0.37	0.66	-0.62	0.93
3	51-195-712	20.71	107.22	1718.29	53.14	52.30	0.84	0.01	0.43	0.52	-0.81	0.87

3	51-195-714	18.16	1837.89	2528.31	780.65	-868.87	0.87	0.01	0.56	-0.17	0.99	1.00
3	51-195-716	28.02	1391.33	1299.17	621.37	-495.67	0.73	0.10	0.50	-0.35	0.76	0.59
3	51-195-719	77.35	1653.11	1058.64	203.86	-837.20	0.59	0.06	0.32	0.87	-0.23	0.24
3	51-195-721	27.97	1812.11	1969.47	313.70	-1084.95	0.85	0.01	0.40	0.79	0.56	0.96
3	51-195-723	20.77	1136.33	2123.07	150.10	-657.74	0.86	0.01	0.36	0.83	0.54	0.94
3	51-195-725	25.62	1680.11	2308.93	409.65	-935.32	0.86	0.01	0.44	-0.34	0.20	1.00
3	51-195-727	17.91	1463.11	2053.15	296.04	-788.85	0.85	0.01	0.38	-0.01	-0.91	0.87
3	51-195-729	27.56	2503.44	2105.07	548.40	-1506.90	0.84	0.02	0.43	-0.99	-0.04	0.92
3	51-195-732	24.93	2123.56	2289.24	469.45	-1192.57	0.86	0.02	0.41	-0.18	0.85	0.88
3	51-195-734	10.13	2527.78	2351.74	551.67	-1481.48	0.86	0.01	0.39	-0.59	0.80	0.97
3	51-195-736	33.35	1870.67	2406.85	380.38	-1076.02	0.86	0.01	0.39	-0.26	0.90	0.99
3	51-195-741	17.63	139.56	1454.27	6.77	-3.37	0.84	0.01	0.24	0.26	-0.96	0.83
3	51-167-227	21.95	2125.78	2439.03	379.67	-1276.19	0.86	0.01	0.37	-0.16	0.55	0.98
3	51-167-241	88.94	1360.11	1895.88	228.34	-636.75	0.79	0.06	0.33	-0.16	-0.82	0.82
3	51-167-247	15.52	1633.44	1973.17	343.18	-871.74	0.84	0.01	0.39	-0.68	-0.71	0.96
3	51-167-253	37.56	1154.00	1742.22	147.83	-524.56	0.81	0.03	0.30	0.73	-0.03	0.51
3	51-167-256	22.92	872.33	1926.95	158.13	-382.37	0.85	0.01	0.35	0.91	0.22	0.64
3	51-167-262	129.91	1435.56	1664.59	273.84	-603.33	0.71	0.07	0.31	-0.48	-0.46	0.43
3	51-167-268	28.80	2185.44	1769.73	453.02	-1140.04	0.76	0.03	0.38	-0.28	0.48	0.56
3	51-167-274	26.44	1643.11	2002.17	334.54	-829.97	0.84	0.01	0.35	0.42	0.64	0.90
3	51-167-280	144.00	2392.22	1693.25	536.26	-1180.85	0.73	0.07	0.38	-0.84	-0.14	0.51
3	51-167-284	26.56	1102.89	1772.52	220.48	-538.15	0.84	0.02	0.38	-0.03	-0.96	0.54
3	51-167-287	25.15	2720.00	2063.06	427.94	-1758.09	0.84	0.01	0.37	-0.34	0.62	1.00
3	51-167-310	20.27	1873.89	1879.95	290.91	-1073.89	0.82	0.02	0.35	-0.65	-0.74	1.00
3	51-167-314	11.79	2243.78	2659.08	440.89	-1315.37	0.87	0.01	0.39	-0.74	0.38	1.00
3	51-167-317	22.63	708.00	1399.69	64.32	-248.49	0.81	0.03	0.31	0.23	-0.96	0.90

3	51-167-321	22.48	1827.89	2108.78	460.18	-973.21	0.85	0.01	0.44	-0.70	-0.39	0.77
3	51-167-324	21.70	3040.78	2290.79	401.56	-1997.90	0.85	0.01	0.35	-0.86	0.48	1.00
3	51-167-328	14.20	703.89	1925.83	83.51	-271.54	0.87	0.02	0.32	0.86	-0.49	0.00
3	51-167-335	19.01	2312.44	1781.47	470.26	-1281.13	0.81	0.02	0.38	-0.91	-0.36	0.84
3	51-167-339	28.12	1914.22	2102.51	359.57	-1092.91	0.85	0.01	0.39	-0.70	-0.30	0.87
3	51-167-342	29.53	3285.11	2082.78	479.76	-1951.42	0.83	0.02	0.33	-0.90	0.43	0.87
3	51-167-346	30.96	2393.67	2407.04	656.28	-992.60	0.81	0.02	0.38	-0.95	-0.17	0.19
3	51-167-349	14.73	2501.11	1873.44	739.50	-1064.92	0.75	0.01	0.40	0.79	0.51	0.99
3	51-167-353	42.17	3328.56	2064.25	647.61	-1772.84	0.77	0.02	0.35	-0.96	0.19	0.74
3	51-167-356	17.84	1691.78	1693.47	259.02	-845.03	0.74	0.05	0.32	0.07	0.12	0.20
3	51-167-365	44.76	2878.89	2162.07	495.86	-1602.19	0.77	0.05	0.34	-0.55	0.83	0.48
3	51-167-368	64.99	2875.78	2023.80	376.14	-1850.07	0.79	0.05	0.35	-0.46	0.53	0.59
3	51-167-372	30.34	2132.11	1609.47	260.01	-1265.18	0.75	0.03	0.31	-0.91	0.14	0.81
3	51-167-375	21.38	1107.67	1609.97	241.81	-533.85	0.81	0.03	0.38	0.92	0.11	0.67
3	51-167-379	95.49	2419.44	1924.34	310.33	-1532.26	0.78	0.11	0.35	-0.29	0.62	0.37
3	51-167-382	26.28	1388.44	1595.19	299.51	-646.65	0.79	0.03	0.38	0.03	-0.61	0.78
3	51-167-384	14.03	1599.78	2266.21	460.98	-864.21	0.86	0.01	0.48	-0.03	0.98	0.79
3	51-167-387	30.58	1321.56	1382.19	141.54	-573.74	0.71	0.05	0.25	0.22	-0.96	0.09
3	51-167-390	53.44	1832.56	1239.05	418.97	-540.90	0.63	0.04	0.33	0.97	-0.25	0.00
3	51-167-392	47.89	2695.56	1679.76	471.22	-1438.13	0.72	0.06	0.34	-0.72	-0.18	0.34
3	51-167-395	61.55	2809.11	2070.15	557.68	-1484.54	0.74	0.02	0.36	-0.85	0.22	0.22
3	51-167-396	15.07	1786.11	2318.80	362.04	-1057.33	0.86	0.01	0.41	0.34	0.77	0.70
3	51-167-399	33.47	1991.56	1953.90	323.53	-1226.68	0.84	0.01	0.38	0.24	0.49	0.47
3	51-167-402	22.94	782.11	1714.51	179.68	-405.79	0.84	0.01	0.42	0.85	-0.34	0.88
3	51-167-406	30.47	1090.00	1303.06	142.81	-395.88	0.69	0.05	0.28	0.94	-0.13	0.04
3	51-167-409	38.68	1947.11	1334.55	323.45	-877.39	0.63	0.04	0.31	-0.07	-0.86	0.00

3	51-167-410	20.19	2014.78	2269.11	444.73	-1151.60	0.86	0.02	0.43	0.23	0.09	0.88
3	51-167-413	19.64	2030.44	2154.61	252.17	-1265.11	0.86	0.01	0.34	0.51	0.85	0.96
3	51-167-416	50.35	2477.89	1897.10	547.28	-985.45	0.74	0.03	0.32	0.32	-0.70	0.00
3	51-167-421	68.53	2240.00	1510.02	730.42	-995.20	0.69	0.03	0.44	0.55	0.34	0.41
3	51-167-422	17.48	1058.67	1849.59	149.41	-581.00	0.84	0.01	0.36	0.55	-0.24	0.84
3	51-167-424	27.67	800.67	1756.21	98.20	-442.10	0.85	0.02	0.33	0.72	-0.37	0.81
3	51-167-426	14.60	1160.89	1702.39	154.07	-558.28	0.84	0.01	0.32	-0.39	-0.91	0.90
3	51-167-429	50.32	1885.22	1295.37	337.49	-860.28	0.68	0.05	0.31	-0.13	-0.98	0.42
3	51-167-430	21.73	583.67	1871.75	154.10	-205.41	0.84	0.01	0.40	0.65	-0.69	0.95
3	51-167-432	23.28	2606.67	2323.08	-373.57	-983.20	0.86	0.01	0.14	-0.64	-0.69	0.75
3	51-167-434	168.44	1941.56	1862.67	523.80	-696.87	0.72	0.08	0.36	0.88	-0.34	0.04
3	51-167-437	15.86	2572.11	1922.79	694.08	-1032.70	0.73	0.02	0.36	-0.27	-0.75	0.00
3	51-167-438	17.33	1055.89	1936.17	242.28	-571.14	0.85	0.01	0.43	-0.07	-0.90	1.00
3	51-167-441	17.04	776.11	1716.62	113.85	-313.64	0.83	0.01	0.34	0.98	0.13	0.91
3	51-167-444	33.79	2246.89	1930.21	526.66	-895.31	0.73	0.01	0.33	0.88	0.30	0.06
3	51-167-446	24.21	2297.11	2829.69	661.95	-898.97	0.84	0.02	0.38	-0.25	0.77	0.00
3	51-167-449	38.93	1486.00	1286.83	426.67	-695.87	0.75	0.05	0.46	-0.05	-0.93	0.44
3	51-167-452	28.51	316.33	1602.34	170.49	-257.45	0.84	0.01	0.84	0.07	-0.98	0.93
3	51-167-454	15.39	2323.11	1985.26	378.82	-1387.30	0.84	0.01	0.37	-0.67	-0.11	0.96
3	51-167-457	31.38	1776.67	2314.04	1018.11	-694.44	0.85	0.01	0.58	-0.92	-0.16	0.86
3	51-167-461	46.56	531.67	1346.29	58.73	4.22	0.75	0.02	0.22	0.53	-0.84	0.45
3	51-167-465	22.76	271.67	1607.24	6.72	-38.11	0.84	0.02	0.28	0.72	-0.63	0.93
3	51-167-468	25.68	1315.22	1571.73	192.70	-689.72	0.82	0.01	0.33	-0.29	-0.94	0.95
3	51-167-471	47.74	1358.11	1781.35	395.77	-638.09	0.80	0.02	0.43	0.24	-0.94	0.50
3	51-167-475	20.33	1314.00	1770.78	222.46	-765.73	0.84	0.01	0.38	0.22	-0.75	0.69
3	51-167-478	14.13	865.56	2312.12	310.86	-339.97	0.85	0.01	0.43	-0.34	-0.93	1.00

3	51-167-480	45.78	2236.22	1921.12	407.93	-1150.07	0.73	0.07	0.34	0.25	-0.92	0.00
3	51-167-483	40.32	2832.11	2087.89	490.96	-1292.31	0.74	0.05	0.29	-0.81	-0.18	0.00
3	51-167-484	19.36	2189.67	1957.37	398.44	-1329.71	0.84	0.01	0.40	-0.82	-0.56	0.94
3	51-167-486	12.58	3367.22	2425.14	-529.35	-1296.40	0.85	0.01	0.12	-0.56	0.72	1.00
3	51-167-488	14.62	2440.78	1787.53	493.94	-1486.05	0.81	0.01	0.43	-0.98	-0.14	0.93
3	51-167-491	22.86	3171.56	2050.57	606.46	-1926.28	0.82	0.05	0.36	-0.63	0.77	0.75
3	51-167-492	20.36	2911.22	2611.53	485.34	-1840.31	0.87	0.01	0.37	-0.73	0.66	0.82
3	51-167-495	25.17	2135.00	1940.63	787.78	-749.60	0.76	0.01	0.43	0.52	-0.82	0.04
3	51-167-496	14.80	2380.44	2359.62	437.78	-1457.24	0.87	0.01	0.38	-0.59	0.41	0.78
3	51-167-498	23.28	1649.00	2058.20	342.60	-926.46	0.82	0.01	0.37	0.77	0.07	0.46
3	51-167-499	47.76	2797.33	1647.55	530.31	-1407.16	0.70	0.03	0.35	-0.80	-0.17	0.16
3	51-167-502	37.72	2916.89	1504.98	626.30	-1588.03	0.66	0.02	0.38	-0.42	-0.40	0.09
3	51-167-503	13.67	784.00	2130.47	95.93	-389.85	0.86	0.01	0.28	0.89	0.25	0.82
3	51-167-505	26.97	761.78	2158.09	589.24	-132.40	0.84	0.01	0.61	-0.77	0.62	0.91
3	51-167-507	26.27	3196.67	1771.03	620.81	-1783.10	0.71	0.06	0.36	-0.88	-0.30	0.06
3	51-167-510	30.73	2029.00	1703.16	1263.36	-442.63	0.70	0.04	0.52	0.41	0.37	0.05
3	51-167-513	12.44	2087.78	2567.13	167.79	-1092.19	0.86	0.01	0.27	-0.29	0.75	1.00
3	51-167-515	34.68	1642.78	1986.23	289.34	-838.04	0.79	0.02	0.33	0.70	0.68	0.34
3	51-167-518	32.68	2891.00	1609.10	516.94	-1359.31	0.70	0.04	0.30	-0.61	-0.77	0.06
3	51-167-522	40.47	2425.44	2116.80	531.52	-1336.06	0.80	0.03	0.40	0.08	0.99	0.44
3	51-167-525	14.09	1190.67	1851.98	156.65	-681.83	0.84	0.02	0.34	0.86	0.46	0.74
3	51-167-526	19.84	1929.56	2523.84	347.47	-1131.60	0.86	0.02	0.38	-0.07	0.73	0.85
3	51-167-529	62.29	2591.78	1393.73	432.90	-1622.84	0.68	0.08	0.38	-0.19	-0.65	0.32
3	51-167-530	16.77	2003.56	2297.46	398.38	-1124.70	0.86	0.01	0.38	-0.73	0.05	0.86
3	51-167-532	16.30	3652.44	2560.87	551.11	-2205.74	0.84	0.01	0.34	-0.48	0.82	0.89
3	51-167-534	19.87	485.89	1568.55	-1.79	-194.72	0.85	0.01	0.27	0.64	-0.75	0.88

3	51-167-537	47.61	2206.44	1785.36	398.44	-1172.19	0.77	0.05	0.35	-0.68	-0.70	0.46
3	51-167-538	21.81	2378.56	2344.63	500.57	-1463.64	0.86	0.01	0.43	-0.34	0.86	0.91
3	51-167-540	18.39	2620.11	2470.91	402.08	-1704.28	0.85	0.01	0.38	0.01	0.97	0.00
3	51-167-542	17.61	2609.78	2343.86	454.98	-1589.77	0.87	0.01	0.37	-0.92	-0.37	0.87
3	51-167-545	22.75	3612.44	1777.99	470.68	-2118.52	0.75	0.01	0.30	-0.34	0.87	0.02
3	51-167-546	27.41	1400.33	1383.68	220.71	-728.34	0.74	0.03	0.35	0.43	-0.04	0.54
3	51-167-549	64.74	2442.11	1440.16	537.99	-1182.80	0.66	0.08	0.37	-0.57	-0.10	0.26
3	51-167-554	21.01	1362.78	1570.72	165.72	-703.20	0.81	0.04	0.31	-0.30	-0.93	0.89
3	51-167-557	27.33	2012.00	1792.66	213.92	-1296.88	0.82	0.03	0.32	0.54	0.16	0.81
3	51-167-558	8.38	1978.11	2241.16	410.32	-1065.40	0.87	0.01	0.38	-0.71	-0.67	0.90
3	51-167-560	19.43	586.22	1817.83	66.69	-175.04	0.82	0.01	0.27	0.69	-0.58	0.86
3	51-167-562	19.03	2065.67	2123.63	246.51	-1283.70	0.85	0.01	0.33	-0.29	-0.06	0.90
3	51-167-565	27.89	2056.11	1602.43	307.02	-1025.28	0.75	0.03	0.30	0.29	0.52	0.33
3	51-167-566	14.73	3755.00	2446.08	676.18	-2433.75	0.86	0.01	0.39	-0.85	0.52	0.82
3	51-167-568	21.31	2785.11	1971.88	381.11	-1760.49	0.81	0.01	0.34	-0.76	-0.06	0.80
3	51-167-570	53.85	1077.67	1741.16	175.93	-532.76	0.80	0.05	0.36	0.72	-0.65	0.61
3	51-167-573	65.64	2382.56	1365.46	663.32	-952.85	0.63	0.08	0.36	0.42	-0.84	0.15
3	51-167-577	26.03	2758.00	1485.63	556.60	-1405.05	0.64	0.04	0.35	-0.75	-0.64	0.00
3	51-167-580	16.24	320.11	1767.79	108.48	-78.83	0.82	0.01	0.41	0.89	0.18	0.76
3	51-167-581	55.37	3632.11	1370.99	619.64	-2067.18	0.62	0.07	0.35	-0.84	-0.43	0.05
3	51-167-585	62.90	2103.33	760.24	345.69	-996.83	0.47	0.08	0.33	-0.32	0.92	0.24
3	51-167-588	30.15	1704.78	1977.47	255.09	-993.69	0.83	0.02	0.36	0.00	0.00	0.84
3	51-167-590	43.27	1903.33	1434.93	408.46	-912.75	0.69	0.03	0.37	0.85	-0.44	0.04
3	51-167-593	54.21	1784.78	1631.50	529.77	-620.66	0.71	0.05	0.38	0.37	-0.35	0.19
3	51-167-594	56.41	2602.78	1550.74	502.39	-1327.24	0.64	0.03	0.34	0.40	0.66	0.05
3	51-167-597	22.81	2413.11	2235.44	330.74	-1527.29	0.84	0.02	0.35	-0.26	0.91	0.79

3	51-167-600	18.19	2706.00	1936.69	550.78	-1019.56	0.72	0.01	0.29	0.78	-0.30	0.02
3	51-167-601	22.14	1823.44	1910.49	268.17	-1074.34	0.84	0.01	0.36	-0.43	-0.77	0.94
3	51-167-604	45.34	3538.78	1455.88	776.48	-1670.32	0.59	0.02	0.34	-0.84	0.53	0.05
3	51-167-607	14.86	121.78	1445.94	46.27	50.80	0.84	0.01	0.32	0.00	0.00	0.65
3	51-167-609	27.09	1945.89	1904.29	533.00	-868.00	0.80	0.04	0.40	-0.93	0.29	0.43
3	51-167-612	62.00	1864.56	1157.23	297.68	-848.30	0.62	0.06	0.31	0.42	-0.62	0.15
3	51-167-616	56.84	1540.89	1678.37	496.61	-557.04	0.75	0.03	0.41	0.27	-0.54	0.30
3	51-167-619	40.87	2372.56	1885.48	570.08	-912.57	0.75	0.03	0.33	0.00	0.00	0.03
3	51-167-620	94.63	2587.89	1045.40	287.17	-1342.99	0.52	0.10	0.28	-0.83	-0.30	0.12
3	51-167-622	27.65	2643.33	1743.64	515.29	-1318.81	0.70	0.02	0.33	0.70	0.21	0.13
3	51-167-626	8.49	577.44	2087.09	183.31	-216.46	0.85	0.01	0.43	0.00	0.00	0.78
3	51-167-627	39.40	1574.22	1221.58	148.00	-825.94	0.68	0.06	0.27	0.31	0.04	0.26
3	51-167-630	21.24	2663.89	1953.59	758.02	-1019.68	0.72	0.02	0.37	0.14	-0.58	0.00
3	51-167-633	23.50	2300.22	1306.66	751.00	-950.43	0.61	0.05	0.42	-0.21	-0.94	0.00
3	51-167-636	25.35	2230.33	2016.34	437.20	-1275.98	0.79	0.04	0.40	0.00	0.00	0.51
3	51-167-640	27.02	258.67	1407.85	-7.06	29.74	0.81	0.04	0.22	0.59	-0.79	0.76
3	51-167-643	63.19	2687.22	1268.13	479.22	-1181.71	0.57	0.06	0.29	0.00	0.00	0.00
3	51-167-644	18.45	1612.33	1651.58	671.75	-769.85	0.80	0.02	0.58	-0.24	0.96	0.90
3	51-167-647	59.36	2778.56	1659.11	449.99	-1455.25	0.69	0.05	0.32	-0.92	-0.16	0.27
3	51-167-650	34.58	2423.00	1482.16	529.48	-1221.91	0.67	0.02	0.37	0.19	-0.49	0.05
3	51-167-653	34.62	2232.44	1492.12	552.33	-1135.06	0.74	0.02	0.41	0.00	0.00	0.52
3	51-167-656	32.16	2200.56	1841.56	537.92	-1285.01	0.80	0.02	0.46	-0.37	0.81	0.83
3	51-167-659	183.88	2500.78	1198.51	559.47	-1045.17	0.49	0.14	0.33	0.00	0.00	0.00
3	51-167-662	13.65	2181.56	2322.08	264.38	-1411.61	0.85	0.01	0.35	0.28	0.95	0.75
3	51-167-665	67.86	2373.22	1513.61	534.43	-1171.20	0.67	0.07	0.38	0.00	0.00	0.17
3	51-167-666	48.28	672.56	1326.50	129.12	-41.83	0.71	0.05	0.23	0.69	-0.67	0.48

3	51-167-668	34.99	1973.78	1607.73	251.26	-910.67	0.73	0.04	0.27	0.48	-0.77	0.00
3	51-167-671	30.73	3251.56	1242.67	584.05	-1925.18	0.59	0.05	0.36	-0.17	0.09	0.00
3	51-167-676	24.84	939.67	1783.54	122.60	-457.93	0.84	0.02	0.32	0.61	-0.32	0.94
3	51-167-679	34.45	2087.56	2281.40	454.31	-993.06	0.79	0.04	0.35	0.00	0.00	0.16
3	51-167-681	39.70	1192.22	1885.89	163.04	-660.25	0.82	0.04	0.34	0.90	-0.34	0.49
3	51-167-683	71.35	2646.44	1579.36	299.66	-1287.68	0.66	0.09	0.27	0.00	0.00	0.12
3	51-167-684	31.38	2437.89	1738.53	831.33	-1270.72	0.78	0.03	0.51	-0.59	0.75	0.70
3	51-167-686	19.26	2911.44	1735.71	888.98	-1154.12	0.74	0.03	0.38	-0.71	-0.39	0.17
3	51-167-688	11.79	476.00	1600.46	17.56	-163.43	0.84	0.01	0.26	0.00	0.00	0.93
3	51-167-689	17.77	1034.00	1977.53	142.02	-491.44	0.85	0.01	0.30	0.81	-0.15	1.00
3	51-167-691	40.86	1582.22	1652.10	597.29	-695.01	0.78	0.09	0.49	-0.90	0.02	0.70
3	51-167-693	15.61	512.67	1692.16	60.22	-127.51	0.85	0.02	0.26	0.50	-0.63	0.94
3	51-167-694	17.69	309.44	1154.16	28.83	-35.60	0.78	0.02	0.24	0.00	0.00	0.86
3	51-167-697	39.14	2666.67	1632.90	522.26	-1464.97	0.70	0.03	0.37	-0.71	-0.09	0.32
3	51-167-699	52.38	1706.67	1893.67	289.44	-759.60	0.80	0.04	0.31	0.00	0.00	0.46
3	51-167-701	28.80	2791.78	1191.36	776.61	-1194.91	0.57	0.01	0.38	-0.84	0.04	0.00
3	51-167-704	46.94	2600.56	1644.07	390.71	-1482.34	0.73	0.05	0.34	-0.36	-0.25	0.34
3	51-167-706	27.14	2567.56	1817.80	412.65	-1538.96	0.81	0.04	0.36	-0.79	-0.58	0.64
3	51-167-709	23.56	1582.22	2202.88	201.27	-938.64	0.86	0.01	0.33	-0.21	-0.88	0.88
3	51-167-713	54.74	2149.00	1825.46	390.50	-1029.46	0.73	0.08	0.32	-0.44	-0.85	0.62

Appendix I: Sample points used to develop model (Chapter 6)

Sample points used to develop model to estimate woody canopy in reclaimed mines as a function of disturbance/recovery parameters, spectral variables from leaf-on (2008) and leaf-off (2009) Landsat images and terrain variables. Ref. canopy is the reference variable developed by photo-interpretation, Rec. time is the recovery time (time since mining).

Pt. ID	X	Y	Ref. canopy	Rec. time	Rslope	Dmin	Rmax	2009 NDVI	2008 NDVI	sin aspect	cos aspect	2008 TC1	2008 TC2	2008 TC3	2009 Band 5	2009 Band 4	2009 TC2	2009 TC3	slope
22	411214.37	4145525.97	0.42	13	0.04	0.57	0.86	0.30	0.85	-0.73	0.40	3038.46	2204.68	212.67	1507	1113	168.01	-816.84	0.02
34	386611.93	4131029.34	0.30	14	0.04	0.45	0.84	0.54	0.81	-0.69	0.79	2277.37	1405.55	-47.46	189	277	-16.36	17.25	0.11
36	416707.62	4130148.29	0.44	13	0.05	0.50	0.87	0.31	0.79	0.73	-0.22	2920.92	1823.54	-28.48	2345	1767	253.77	-1414.09	0.16
44	390878.54	4127192.18	0.21	9	0.08	0.31	0.86	0.43	0.83	-0.31	0.92	3174.11	2170.33	-6.67	1427	814	192.04	-981.96	0.06
45	407893.49	4123368.12	0.56	15	0.03	0.26	0.67	0.53	0.82	0.98	-0.12	3332.84	2217.59	-2.71	2038	1897	670.16	-1063.86	0.12
46	387657.45	4124004.08	0.20	13	0.04	0.56	0.91	0.36	0.76	0.88	-0.37	3513.97	1965.96	-407.92	3543	2123	507.32	-2353.05	0.14
47	388340.93	4124295.54	0.46	13	0.04	0.56	0.90	0.32	0.78	0.74	0.09	3065.15	1850.92	-41.77	1147	874	145.66	-652.64	0.10
48	408149.77	4122357.24	0.54	20	0.07	0.22	0.73	0.33	0.79	0.68	0.49	2702.66	1665.82	-96.31	1431	1172	255.65	-772.91	0.22
49	382329.52	4121640.49	0.19	12	0.06	0.22	0.84	0.36	0.77	0.71	0.40	3810.17	2008.29	-720.83	2826	2005	451.05	-1697.03	0.08
50	382446.87	4121631.48	0.55	12	0.05	0.32	0.83	0.35	0.75	0.92	-0.27	3443.40	1774.38	-631.98	3824	2599	636.41	-2266.99	0.12
51	394461.27	4121524.27	0.51	17	0.04	0.36	0.77	0.42	0.80	0.88	0.43	3077.34	1988.59	23.08	1626	1945	909.58	-658.73	0.06
58	391098.09	4119615.97	0.46	15	0.02	0.55	0.73	0.51	0.84	-0.41	0.90	2800.52	1980.54	201.88	1227	1528	649.51	-397.75	0.06
62	367694.36	4116637.25	0.35	13	0.04	0.52	0.88	0.38	0.81	0.54	-0.80	3593.87	2285.68	-130.62	3827	2305	681.49	-2573.15	0.13
65	379676.69	4115276.18	0.25	11	0.09	0.16	0.82	0.34	0.76	0.98	0.06	3376.36	1752.57	-562.28	3502	2241	518.76	-2134.24	0.14
66	379588.63	4115491.3	0.48	11	0.10	0.13	0.76	0.33	0.76	0.95	-0.14	3395.67	1909.09	-260.34	2944	2003	443.30	-1703.46	0.07
67	369592.96	4115177.61	0.16	9	0.04	0.50	0.79	0.30	0.79	0.96	-0.09	3388.39	2106.68	-75.04	2946	2421	532.73	-1392.24	0.07
69	381040.6	4114688.06	0.19	10	0.04	0.40	0.76	0.32	0.80	0.53	0.73	3320.16	2122.86	-55.08	2026	1172	228.21	-1317.85	0.12
70	371816.9	4114546.72	0.43	21	0.04	0.45	0.70	0.41	0.76	-0.39	-0.17	3151.69	1697.53	-370.54	2072	1772	544.17	-998.74	0.02

71	413667.63	4114535.25	0.28	20	0.03	0.57	0.82	0.25	0.74	-0.01	-0.80	3365.44	1850.22	-176.06	3144	2242	328.48	-1879.74	0.12
72	411606.04	4114288.42	0.28	9	0.07	0.23	0.74	0.29	0.68	-0.13	0.70	2300.51	1059.80	-210.57	828	993	143.38	-136.30	0.16
74	409857.76	4112282.67	0.72	17	0.05	0.21	0.78	0.55	0.80	-0.24	-0.20	2570.03	1685.37	117.18	1231	1834	805.26	-286.87	0.04
78	366567.73	4112640.33	0.45	17	0.05	0.30	0.74	0.37	0.73	0.80	0.20	3239.31	1585.20	-593.73	1867	1947	673.13	-739.22	0.04
79	368818.68	4112636.19	0.16	10	0.07	0.17	0.66	0.32	0.70	-0.17	-0.89	3368.33	1652.53	-434.54	2632	1711	311.17	-1614.97	0.10
80	342143.61	4088310.15	0.07	7	0.03	0.39	0.74	0.33	0.69	-0.96	-0.26	2695.20	1170.92	-585.66	2225	1290	280.73	-1353.43	0.06
81	370921.14	4111157.38	0.51	15	0.04	0.25	0.73	0.35	0.71	-0.80	0.34	2637.42	1503.76	100.21	1108	1648	509.46	-94.97	0.02
83	409003.02	4109556.76	0.05	9	0.06	0.40	0.81	0.31	0.76	-0.44	-0.76	3399.68	2022.67	-98.44	2665	2064	540.47	-1429.72	0.11
84	363728.77	4109099.59	0.61	21	0.04	0.54	0.80	0.34	0.74	0.69	0.67	2874.78	1585.04	-211.20	1467	874	99.03	-935.18	0.11
85	362720.15	4107672.62	0.61	20	0.05	0.17	0.65	0.30	0.83	-0.83	0.45	2776.99	1843.48	-10.77	1187	1053	215.02	-509.57	0.06
86	354826.25	4108682	0.54	16	0.04	0.37	0.80	0.35	0.80	0.97	0.05	3723.52	2302.68	-270.76	2876	2073	568.01	-1578.30	0.12
87	375588.82	4108494.27	0.46	9	0.04	0.49	0.78	0.29	0.74	0.93	0.07	3540.77	1941.06	-166.11	2465	1528	155.90	-1586.19	0.07
88	414604.97	4108474.19	0.06	10	0.08	0.21	0.71	0.30	0.80	0.18	0.19	3121.27	2091.91	152.86	1787	1469	272.74	-849.09	0.03
89	363298.42	4108183.81	0.47	16	0.04	0.28	0.66	0.42	0.76	-0.70	0.66	2582.31	1517.74	-105.23	429	695	82.22	60.09	0.12
91	362937.4	4107905.58	0.49	16	0.04	0.34	0.69	0.36	0.83	-0.51	-0.85	3162.90	2100.49	-107.32	2823	1825	437.54	-1758.96	0.11
92	376966.97	4108131.47	0.48	15	0.04	0.55	0.88	0.39	0.81	0.98	-0.13	3022.50	1947.14	-146.22	2823	1825	480.73	-1891.79	0.16
93	397957.22	4107779.35	0.58	8	0.02	0.51	0.86	0.31	0.82	-0.31	-0.84	3213.31	2033.75	-213.49	2827	1649	434.99	-1904.32	0.13
94	362338.02	4107504.38	0.76	20	0.07	0.16	0.72	0.37	0.80	0.47	0.87	2972.57	1863.82	-45.26	1507	1290	321.52	-699.40	0.10
95	365120.74	4106703.52	0.18	8	0.07	0.19	0.77	0.22	0.80	0.23	0.92	2743.53	1744.74	-4.89	868	635	30.29	-414.86	0.15
96	364953.19	4106785.94	0.31	8	0.04	0.40	0.79	0.27	0.74	-0.49	0.78	2424.80	1360.61	-85.81	629	695	109.07	-117.77	0.14
97	411634.34	4106140.42	0.50	19	0.07	0.28	0.79	0.30	0.83	0.22	-0.71	3529.01	2435.45	104.65	2944	1766	340.34	-1860.10	0.09
98	357399.58	4106135.28	0.73	19	0.05	0.34	0.77	0.37	0.86	0.06	-0.46	3411.59	2443.71	62.50	2867	1827	452.92	-1828.94	0.06
99	353732.43	4105357.05	0.05	8	0.05	0.37	0.76	0.37	0.72	-0.33	-0.03	3512.21	1736.09	-650.15	2031	1830	483.14	-888.04	0.04
100	348890.65	4104121.31	0.41	8	0.07	0.15	0.71	0.26	0.74	-0.81	0.57	2401.74	1272.16	-249.19	628	566	77.26	-236.48	0.10
101	355019.41	4104174.39	0.71	19	0.04	0.58	0.80	0.37	0.84	0.45	0.22	3231.40	2143.76	-128.43	2229	1232	249.33	-1484.64	0.13
103	349410.26	4103340.1	0.68	18	0.04	0.37	0.79	0.55	0.79	0.04	0.97	2111.94	1396.97	163.44	226	445	145.91	22.10	0.12
104	346954.56	4103325.86	0.25	11	0.10	0.08	0.71	0.29	0.73	-0.25	0.96	2594.72	1338.15	-224.24	1152	869	141.23	-589.05	0.08

105	346961.09	4103270.93	0.55	11	0.08	0.09	0.60	0.26	0.80	-0.32	0.94	2903.88	1783.99	-15.42	1394	989	174.53	-741.60	0.10
106	353347.35	4102760.2	0.49	19	0.08	0.21	0.77	0.41	0.81	-0.73	-0.02	2908.55	2028.35	299.96	1349	1411	407.17	-486.78	0.11
107	365040.64	4108040.76	0.08	7	0.02	0.56	0.86	0.38	0.76	0.39	-0.86	3437.98	1932.45	-371.52	3183	2003	512.10	-2077.57	0.13
108	352757	4102496.64	0.54	11	0.06	0.19	0.66	0.29	0.81	0.93	0.34	3487.46	2196.37	-164.96	1990	1172	177.05	-1300.38	0.19
109	360066.18	4102563.78	0.48	17	0.04	0.23	0.77	0.54	0.78	0.94	0.27	3209.22	1753.99	-361.89	2354	2490	1072.62	-1051.76	0.07
110	360019.3	4102416.41	0.35	17	0.04	0.22	0.85	0.43	0.78	0.60	0.76	3013.30	1871.59	-40.99	1792	1892	641.85	-677.61	0.08
112	351938.95	4100944.59	0.37	21	0.08	0.20	0.74	0.28	0.71	0.16	0.85	2678.56	1464.51	-28.65	910	688	-20.45	-434.54	0.03
113	352566.76	4100837.94	0.44	19	0.08	0.17	0.78	0.47	0.79	-0.53	0.82	2262.62	1503.92	170.31	427	629	153.54	-33.98	0.10
114	350273.13	4099796.73	0.77	18	0.07	0.16	0.68	0.58	0.78	0.55	0.82	2599.38	1663.83	108.08	989	1292	362.07	-176.76	0.08
115	350759.43	4099664.36	0.73	21	0.06	0.17	0.59	0.21	0.75	0.38	0.44	2663.82	1452.39	-179.05	1191	990	94.71	-518.17	0.08
116	411209.1	4098867.72	0.69	18	0.04	0.55	0.84	0.32	0.86	0.97	0.03	3252.77	2385.66	111.66	2191	1351	290.86	-1359.26	0.14
117	376381.95	4096319.36	0.04	8	0.05	0.47	0.88	0.47	0.85	-0.96	0.10	3284.80	2454.58	279.49	1227	1290	431.61	-516.77	0.02
118	346884.27	4093383.99	0.61	21	0.08	0.21	0.77	0.35	0.79	-0.57	-0.71	3089.93	1931.12	-20.30	2106	1350	324.43	-1287.71	0.05
119	350615.38	4092938.84	0.52	19	0.03	0.34	0.61	0.32	0.66	-0.79	-0.12	3021.74	1522.55	-109.26	1228	872	174.79	-687.52	0.07
120	366209.73	4088109.76	0.11	7	0.03	0.33	0.82	0.39	0.70	-0.68	-0.60	3159.25	1573.20	-268.12	2511	2188	561.78	-1104.84	0.06
122	342352	4089229.34	0.10	7	0.04	0.25	0.80	0.28	0.73	-0.64	-0.76	3171.27	1680.63	-227.85	2545	1410	170.34	-1673.33	0.10
139	385624.17	4116060.72	0.70	18	0.08	0.26	0.86	0.40	0.82	0.65	-0.22	2967.85	2006.22	132.76	1826	1529	438.30	-997.72	0.04
140	385655.7	4116212.26	0.61	16	0.06	0.30	0.84	0.39	0.84	0.80	0.39	3161.10	2052.41	-190.96	1827	1647	607.07	-944.49	0.08
141	370136.2	4112013	0.61	17	0.04	0.57	0.86	0.24	0.82	0.36	0.82	2554.01	1740.04	120.75	628	570	39.17	-243.45	0.16
142	409768.31	4112001.57	0.48	17	0.04	0.22	0.79	0.67	0.81	0.94	-0.12	3300.96	2244.87	122.54	1471	3624	2067.82	190.46	0.08
143	349194.93	4102887.1	0.60	17	0.07	0.21	0.81	0.38	0.82	-0.06	0.75	2683.81	1748.08	42.03	1030	749	156.72	-579.03	0.08
144	349501.68	4103190.91	0.71	17	0.06	0.22	0.72	0.62	0.81	0.04	0.98	2919.17	1945.94	78.34	789	1414	690.73	-121.28	0.11
145	349590.17	4103245.48	0.43	16	0.03	0.25	0.75	0.31	0.79	-0.80	0.39	2321.89	1484.97	203.53	628	870	351.42	-129.58	0.08
146	351302.91	4102350.92	0.61	16	0.06	0.25	0.80	0.76	0.82	-0.58	-0.59	2889.82	1910.49	103.62	1189	2008	1062.23	-246.63	0.11
147	351270.43	4102290.29	0.68	16	0.06	0.26	0.82	0.62	0.83	0.59	0.03	3274.67	2296.56	292.95	1429	2723	1546.40	-172.07	0.10
148	350372.47	4104782.64	0.31	16	0.02	0.27	0.72	0.57	0.79	0.19	-0.73	2761.55	1715.83	53.42	1753	2013	743.69	-622.46	0.05

149	360959.5	4105650.35	0.39	16	0.04	0.34	0.82	0.45	0.82	-0.35	0.90	2563.12	1770.44	148.61	709	870	333.51	-209.96	0.10
150	360660.19	4105589.32	0.75	16	0.06	0.23	0.74	0.76	0.84	-0.14	-0.97	3030.99	2145.55	347.04	1151	2797	1578.22	119.50	0.13
151	360510.54	4106007.77	0.68	16	0.04	0.48	0.86	0.56	0.81	0.75	0.10	3174.10	2016.25	-95.08	1877	1717	726.38	-964.98	0.08
152	370257.91	4111645.49	0.66	18	0.08	0.23	0.83	0.53	0.84	0.23	0.92	2836.30	2075.44	249.85	628	932	328.54	-136.55	0.14
154	361049.58	4105590.78	0.49	16	0.03	0.25	0.82	0.63	0.82	-0.58	0.81	2254.16	1524.53	187.07	306	809	388.56	110.62	0.13
155	360086.29	4106099.3	0.53	15	0.02	0.44	0.79	0.73	0.80	-0.92	0.38	2333.14	1535.57	125.00	387	1112	559.74	155.80	0.13
156	360779.33	4105733.16	0.66	15	0.04	0.29	0.75	0.35	0.84	0.96	0.25	3291.01	2249.01	54.21	2076	2317	1069.24	-935.78	0.15
157	360115.71	4106761.67	0.73	15	0.05	0.34	0.80	0.58	0.81	-0.20	-0.97	3021.59	1976.64	94.53	1957	2558	1253.73	-641.64	0.12
158	360422.42	4106853.3	0.55	15	0.04	0.26	0.76	0.66	0.82	0.53	0.82	2735.17	1901.24	236.00	507	990	434.87	20.01	0.20
159	362907.58	4106397.15	0.53	15	0.04	0.21	0.77	0.43	0.80	0.90	-0.43	3184.38	2089.01	66.91	2665	2241	725.71	-1366.02	0.10
160	362702.13	4103276.17	0.57	14	0.05	0.39	0.80	0.63	0.78	0.75	-0.41	2968.01	1880.82	202.54	1876	2559	1248.18	-584.04	0.10
161	354364.59	4107451.16	0.30	14	0.05	0.43	0.86	0.39	0.86	0.67	-0.60	3439.29	2456.48	80.79	2707	1827	548.95	-1653.09	0.06
162	352229.27	4103491.85	0.37	14	0.04	0.23	0.64	0.40	0.83	0.96	0.23	3725.68	2593.99	103.21	2991	1950	464.43	-1861.01	0.20
163	384510.25	4112132.22	0.56	14	0.07	0.25	0.84	0.42	0.80	0.79	-0.52	3262.48	2172.93	274.45	1508	2953	1633.77	-61.65	0.04
164	384719.18	4112310.88	0.54	14	0.03	0.53	0.78	0.58	0.77	0.00	-0.99	3074.50	1866.41	26.78	1987	2656	1209.84	-658.15	0.13
165	391741.77	4117652.43	0.54	13	0.06	0.40	0.80	0.25	0.82	-0.72	0.44	2253.63	1565.22	206.11	268	455	68.52	52.76	0.13
166	393363.22	4117290.31	0.51	13	0.07	0.33	0.88	0.50	0.83	0.01	-1.00	3391.88	2349.45	146.29	2784	2123	816.45	-1670.29	0.12
167	362907.46	4111498.49	0.49	13	0.05	0.43	0.85	0.47	0.78	0.33	0.93	2358.19	1526.08	137.06	668	814	302.66	-206.65	0.17
168	363152.69	4110960.4	0.55	13	0.07	0.39	0.83	0.42	0.79	0.97	-0.02	3212.51	2009.28	-97.87	2505	1945	666.88	-1426.01	0.13
169	363538.67	4111140.95	0.55	13	0.06	0.45	0.83	0.24	0.83	0.31	-0.89	3242.65	2119.26	-152.11	2904	1885	245.71	-1714.26	0.12
172	384815.29	4112340.47	0.54	12	0.04	0.48	0.76	0.55	0.78	0.93	-0.28	3351.65	2009.02	-68.45	2226	2597	1137.01	-951.97	0.14
173	393904.56	4117434.56	0.73	12	0.08	0.23	0.81	0.58	0.81	-0.35	-0.87	2961.23	1947.29	84.94	2186	2241	1016.00	-992.60	0.12
174	393991.32	4117314.89	0.65	12	0.07	0.21	0.82	0.50	0.79	-0.97	0.14	2593.05	1710.22	121.80	828	1113	438.77	-228.65	0.15
175	393302.22	4117470.46	0.63	12	0.08	0.20	0.79	0.63	0.82	-0.76	-0.03	2898.16	1992.68	198.22	1227	1825	919.28	-329.54	0.01
176	393421.89	4117563.21	0.57	12	0.08	0.18	0.79	0.58	0.84	0.09	0.92	2944.51	2026.79	139.74	948	1290	528.09	-292.64	0.06
178	398222.26	4120559.34	0.44	11	0.05	0.29	0.77	0.30	0.77	-0.72	-0.46	2898.41	1646.18	-283.49	2665	2003	385.48	-1344.02	0.06

180	365311.61	4111707.76	0.62	11	0.04	0.49	0.74	0.43	0.82	0.17	0.86	2927.04	1928.52	-6.66	908	1113	326.01	-244.31	0.13
181	364415.28	4104093.84	0.53	11	0.05	0.13	0.76	0.41	0.81	0.86	-0.45	3378.39	2090.37	-168.10	2944	2182	758.29	-1757.85	0.14
182	365552.34	4104934.44	0.49	10	0.09	0.19	0.80	0.32	0.81	0.59	0.80	3107.35	2073.80	109.71	1429	1112	304.73	-751.95	0.11
183	352710.1	4102414.1	0.56	10	0.07	0.18	0.83	0.32	0.86	0.87	0.47	3826.50	2817.89	187.81	2311	1412	252.57	-1468.64	0.23
184	379435.37	4115097.9	0.34	10	0.06	0.15	0.82	0.36	0.75	0.93	0.15	3223.65	1723.24	-457.68	3303	2123	472.68	-2030.92	0.10
185	355349.73	4102945.61	0.63	10	0.04	0.54	0.89	0.39	0.89	0.95	-0.23	3948.70	3128.68	300.09	3348	2066	563.22	-2162.44	0.16
186	352078.9	4104327.37	0.23	9	0.07	0.16	0.78	0.38	0.78	0.75	0.59	3379.98	2046.54	-198.41	3353	1890	527.74	-2254.57	0.13
187	351840.29	4103247.89	0.26	9	0.10	0.12	0.78	0.23	0.80	0.13	0.98	2926.60	1893.23	40.98	1229	872	24.97	-663.92	0.08
188	349413.4	4097217.02	0.26	9	0.07	0.08	0.73	0.41	0.76	0.33	0.85	2740.93	1592.67	-95.14	1671	1171	346.90	-956.64	0.12
189	364349.27	4111649.03	0.49	9	0.02	0.50	0.83	0.32	0.76	-0.02	-0.24	3260.20	1719.40	-577.15	2227	1469	365.70	-1302.05	0.02
190	363990.45	4113686.82	0.61	9	0.02	0.53	0.87	0.39	0.83	0.52	-0.32	3331.86	2216.43	-132.59	3024	1707	417.94	-2009.42	0.13
191	359761.83	4107747.72	0.45	9	0.05	0.39	0.80	0.34	0.82	0.64	0.65	3555.62	2290.46	-176.84	2628	1828	413.76	-1514.14	0.11
192	359941.51	4107450.76	0.36	9	0.06	0.45	0.86	0.34	0.83	0.80	0.59	3363.11	2251.96	32.04	1869	1411	339.26	-992.87	0.13
193	350008.07	4089475.46	0.36	8	0.06	0.29	0.80	0.37	0.78	-0.74	-0.62	3048.58	1811.08	-175.52	1797	1596	453.42	-835.73	0.09
194	349702.95	4089689.15	0.20	8	0.07	0.28	0.84	0.51	0.85	0.44	0.84	2712.87	1908.86	150.50	467	869	331.58	22.63	0.09
195	365105.67	4106786.41	0.42	8	0.05	0.39	0.79	0.37	0.81	0.87	0.42	3248.16	2062.08	-183.14	2784	1647	399.85	-1821.21	0.12
196	364470.33	4106935.49	0.50	8	0.04	0.55	0.83	0.35	0.80	0.85	-0.02	3582.70	2369.62	19.30	1706	1231	323.73	-981.21	0.08
197	364799.95	4105651.97	0.24	8	0.03	0.57	0.80	0.27	0.80	0.56	0.79	2618.94	1784.56	230.29	468	513	45.08	-82.94	0.18
198	364773.2	4108227.94	0.20	7	0.08	0.26	0.85	0.38	0.85	0.11	-0.80	3076.45	2137.07	60.91	1587	993	126.96	-1007.96	0.03
199	359160.73	4100791.17	0.23	7	0.06	0.35	0.80	0.37	0.80	0.71	0.66	2927.94	1874.98	-44.01	1667	1350	326.44	-792.21	0.15
200	354444.83	4106881.18	0.28	7	0.03	0.35	0.87	0.35	0.77	-0.70	-0.48	2716.80	1626.27	-148.71	1512	1232	284.70	-760.92	0.02
201	389672.78	4092033.93	0.40	7	0.06	0.24	0.75	0.30	0.71	0.79	-0.15	3133.41	1434.32	-652.07	2744	1410	247.14	-1818.51	0.05
202	389969.22	4091758.88	0.32	7	0.04	0.31	0.74	0.36	0.73	0.69	-0.35	2732.70	1411.12	-349.81	1547	1172	249.41	-741.58	0.05
203	388506.14	4092900.42	0.21	7	0.07	0.28	0.76	0.36	0.76	0.71	0.64	3211.79	1898.07	-84.12	1308	1172	234.24	-539.89	0.11
204	380336.18	4096255.74	0.32	7	0.04	0.40	0.81	0.37	0.69	0.83	0.21	3044.84	1551.29	-187.38	2625	1647	468.41	-1585.76	0.18
123	349351.98	4103908.76	0.86	21	0.04	0.23	0.78	0.63	0.85	0.87	0.36	2966.86	2085.63	75.78	1392	1534	748.13	-563.18	0.10
124	363961.82	4108500.81	0.72	21	0.03	0.57	0.88	0.35	0.84	0.94	0.10	3048.63	2088.46	18.66	2225	1469	314.55	-1368.49	0.09

125	364408.74	4108649.18	0.62	21	0.04	0.49	0.80	0.39	0.83	-0.51	-0.30	2147.80	1443.82	114.78	748	695	153.46	-331.24	0.08
126	364623.04	4108052.06	0.77	21	0.04	0.52	0.82	0.43	0.83	0.15	-0.97	3123.29	2139.22	110.99	2744	1767	499.79	-1795.72	0.11
127	366571.66	4107631.34	0.53	21	0.04	0.43	0.76	0.34	0.79	0.88	-0.42	3178.80	2000.40	-49.17	2665	1707	450.06	-1589.89	0.07
128	352675.06	4101927.97	0.48	20	0.05	0.14	0.56	0.46	0.80	-0.60	-0.76	2963.00	1900.96	24.77	1594	1835	818.60	-633.63	0.08
129	353308.46	4102024.68	0.64	20	0.06	0.16	0.69	0.32	0.84	-0.96	-0.24	2815.44	1931.56	35.00	1271	1292	606.53	-584.53	0.06
130	359431.74	4105528.42	0.72	20	0.04	0.45	0.77	0.47	0.85	0.52	0.69	2339.27	1719.05	169.19	388	332	46.85	-180.90	0.15
131	359612.7	4105620.91	0.55	20	0.04	0.35	0.71	0.43	0.76	0.89	0.33	3308.28	1838.50	-294.96	1791	1532	481.24	-899.74	0.06
132	369720.07	4109697.98	0.73	20	0.08	0.17	0.87	0.74	0.86	-0.38	-0.89	2924.18	2202.96	324.57	1387	1826	811.90	-366.07	0.11
133	369272.01	4110064.37	0.65	20	0.09	0.24	0.86	0.55	0.83	0.21	-0.93	2889.54	2014.60	131.14	1906	2064	882.48	-835.21	0.08
134	357452.05	4105199.33	0.75	19	0.07	0.17	0.80	0.61	0.80	-0.68	0.71	2382.82	1570.58	105.42	547	991	460.27	-16.03	0.09
135	362822.47	4108412.53	0.72	19	0.06	0.20	0.75	0.32	0.83	0.30	-0.89	3496.37	2282.63	-170.01	3741	1945	411.69	-2598.47	0.10
136	385617.18	4116685.46	0.64	19	0.08	0.20	0.84	0.26	0.82	-0.28	0.88	2450.73	1639.27	129.28	668	933	236.04	-35.16	0.12
137	362733.62	4107955.59	0.73	19	0.07	0.15	0.72	0.39	0.82	0.60	-0.77	3095.97	1993.18	-83.00	2384	1528	334.06	-1440.10	0.05
138	369362.25	4111709.69	0.59	18	0.07	0.22	0.82	0.76	0.83	0.75	0.58	3016.09	2163.38	335.94	1310	2129	1087.70	-313.82	0.16

Appendix J: Best subset results (Chapter 5)

Best subset results for mines

Response is Ref. canopy

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	2008_b7_fst	2008_b4_fst	2009_b4_fcm	2009b4_fst	2009b1_fst	2008_tc1_fcm	2008_tc1_fst	2009_tc2_fcm	2009_tc3_fcm	2009_tc2_fst	2009_tc3_fst	2008_ndvi_fcm	2008_ndvi_fst	2009_ndvi_fcm	2009ndvi_fst	2009_temp_fst	aspect_fcm	aspect_fst	cos_fcm
1	49.3	48.9	79.6	0.24726												X							
1	37.4	36.9	129.1	0.27476														X					
2	55.3	54.6	56.7	0.23302			X									X							
2	53.4	52.7	64.6	0.23796									X			X							
3	60.5	59.6	37.0	0.21982								X				X		X					
3	59.8	58.9	40.0	0.22188			X									X							X
4	63.9	62.8	24.9	0.21102			X									X		X					X
4	63.3	62.1	27.7	0.21296								X				X		X					X
5	65.6	64.3	20.0	0.20689			X									X	X	X					X
5	65.5	64.2	20.2	0.20705								X				X	X	X					X
6	67.3	65.8	14.8	0.20235							X	X				X	X	X					X
6	67.3	65.8	14.8	0.20242			X		X							X	X	X					X
7	68.7	67.0	11.0	0.19882			X		X							X	X	X					X
7	68.5	66.7	12.0	0.19954			X		X							X	X	X			X		X
8	69.7	67.8	8.9	0.19644			X		X							X	X	X					X
8	69.7	67.7	9.1	0.19654			X		X	X						X	X	X					X
9	71.1	69.0	5.3	0.19275			X		X	X						X	X	X			X		X
9	70.9	68.8	5.9	0.19322			X		X	X						X	X	X					X
10	71.6	69.4	4.8	0.19153			X		X	X						X	X	X			X	X	X
10	71.4	69.1	5.9	0.19240			X		X	X						X	X	X				X	X
11	72.2	69.7	4.6	0.19048			X		X	X						X	X	X			X	X	X
11	72.0	69.5	5.4	0.19117			X	X	X	X						X	X	X			X	X	X
12	72.3	69.6	5.9	0.19071			X		X	X				X		X	X	X			X	X	X
12	72.3	69.6	6.0	0.19074			X		X	X		X				X	X	X			X	X	X
13	72.6	69.7	6.7	0.19045			X		X	X				X		X	X	X	X		X	X	X
13	72.5	69.6	7.2	0.19085			X		X	X	X			X		X	X	X			X	X	X
14	72.8	69.6	8.1	0.19072			X		X	X	X			X		X	X	X	X		X	X	X
14	72.8	69.6	8.1	0.19073			X		X	X			X	X		X	X	X	X		X	X	X
15	73.0	69.6	9.1	0.19073			X		X	X		X	X	X		X	X	X	X		X	X	X
15	72.9	69.5	9.4	0.19100			X		X	X	X	X		X		X	X	X	X		X	X	X
16	73.2	69.6	10.4	0.19092			X		X	X	X	X	X	X		X	X	X	X		X	X	X
16	73.2	69.5	10.5	0.19103			X		X	X		X	X	X		X	X	X	X	X	X	X	X
17	73.3	69.4	11.9	0.19129			X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
17	73.3	69.4	11.9	0.19133		X	X		X	X	X	X	X	X		X	X	X	X		X	X	X
18	73.5	69.4	13.2	0.19151	X	X	X		X	X	X	X	X	X		X	X	X	X		X	X	X

18	73.4	69.3	13.4	0.19169	X	X	X		X	X	X	X	X	X		X		X	X	X	X	X	X
19	73.6	69.3	14.5	0.19178	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
19	73.5	69.2	15.0	0.19217	X	X	X		X	X	X	X	X	X		X	X	X	X		X	X	X

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	2008_b7fst	2008_b4fst	2009_b4fcm	2009b4fst	2009b1fst	2008_tc1_fcm	2008_tc1_fst	2009_tc2_fcm	2009_tc3_fcm	2009_tc2_fst	2009_tc3_fst	2008_ndvi_fcm	2008_ndvi_fst	2009_ndvi_fcm	2009ndvi_fst	2009_temp_fst	aspect_fcm	aspect_fst	cos_fcm
20	73.7	69.1	16.2	0.19235	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
20	73.7	69.0	16.4	0.19251	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
21	73.7	68.9	18.1	0.19306	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
21	73.7	68.8	18.2	0.19314	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
22	73.8	68.6	20.0	0.19386	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X
22	73.8	68.6	20.1	0.19391	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
23	73.8	68.3	22.0	0.19473	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
23	73.8	68.3	22.0	0.19473	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
24	73.8	68.0	24.0	0.19560	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24	73.8	68.0	24.0	0.19560	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
25	73.8	67.8	26.0	0.19649	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Vars	cos_fst	sin_fcm	sin_fst	slope_fcm	slope_fst	dem_fcm
1						
1						
2						
2						
3						
3						
4						
4						
5						
5						
6						
6						
7		X				
7						
8		X		X		

8		X				
9				X		
9		X		X		
10				X		
10		X		X		

Vars	cos_fst	sin_fcm	sin_fst	ope_fcm	lope_fst	ldem_fcm
11				X	X	
11				X		
12				X	X	
12				X	X	
13				X	X	
13				X	X	
14				X	X	
14				X	X	
15				X	X	
15				X	X	
				s	s	
16				X	X	
16				X	X	
17				X	X	
17				X	X	
18				X	X	
18				X	X	
19				X	X	
19			X	X	X	
20			X	X	X	
20				X	X	X
21			X	X	X	X
21		X	X	X	X	
22		X	X	X	X	X
22			X	X	X	X
23		X	X	X	X	X
23		X	X	X	X	X
24	X	X	X	X	X	X
24	X	X	X	X	X	X
25	X	X	X	X	X	X

Best subset results for non-mines (Chapter 5)

Response is Ref. canopy

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	2008_b4fst	2008_b1fst	2009b7fst	2009b1fst	2008_tc2_fcm	2008_tc3_fcm	2008_tc3_fst	2009_tc2_fcm	2009_tc3_fcm	2008_ndvi_fcm	2008_ndvi_fst	2009_ndvi_fcm	2009ndvi_fst	2009_temp_fst	aspect_fcm	aspect_fst	cos_fcm	cos_fst	sin_fcm
1	51.7	51.6	220.6	0.19864										X									
1	49.6	49.5	255.0	0.20298						X													
2	56.1	56.0	151.0	0.18943						X				X									
2	53.6	53.4	192.0	0.19486						X						X							
3	57.5	57.3	130.9	0.18662						X				X		X							
3	57.5	57.2	131.7	0.18673					X	X				X									
4	59.9	59.6	94.8	0.18151					X	X				X		X							
4	59.7	59.4	97.9	0.18194					X	X				X							X		
5	62.6	62.3	52.3	0.17530					X	X			X	X		X							
5	61.5	61.2	70.0	0.17786						X		X		X		X					X		
6	63.7	63.3	36.9	0.17290	X				X	X			X	X		X							
6	63.5	63.1	41.1	0.17351					X	X		X	X	X		X							
7	64.4	64.0	27.5	0.17135	X				X	X		X	X	X		X							
7	64.2	63.8	30.5	0.17181					X	X		X		X		X					X		X
8	65.2	64.7	17.4	0.16968	X				X	X		X		X		X					X		X
8	64.9	64.4	21.5	0.17031	X				X	X		X	X	X		X					X		
9	65.8	65.2	9.5	0.16833	X				X	X		X	X	X		X					X		X
9	65.5	64.9	14.9	0.16917	X				X	X	X	X		X		X					X		X
10	66.1	65.5	7.2	0.16784	X				X	X	X	X	X	X		X					X		X
10	66.0	65.4	8.5	0.16803	X				X	X		X	X	X	X	X					X		X
11	66.2	65.5	7.2	0.16767	X	X			X	X	X	X	X	X		X					X		X
11	66.2	65.5	7.3	0.16769	X	X			X	X		X	X	X	X	X					X		X
12	66.3	65.6	7.5	0.16757	X	X			X	X	X	X	X	X		X					X		X
12	66.3	65.6	7.5	0.16757	X	X			X	X	X	X	X	X	X	X					X		X
13	66.4	65.6	8.1	0.16751	X	X			X	X	X	X	X	X	X	X					X		X
13	66.4	65.6	8.4	0.16755	X	X	X		X	X	X	X	X	X	X	X					X		X
14	66.5	65.6	8.9	0.16747	X	X	X		X	X	X	X	X	X		X					X	X	X
14	66.4	65.6	9.2	0.16751	X	X			X	X	X	X	X	X	X	X					X	X	X
15	66.5	65.6	9.9	0.16746	X	X	X		X	X	X	X	X	X	X	X					X	X	X
15	66.5	65.6	10.1	0.16750	X	X	X		X	X	X	X	X	X		X					X	X	X
16	66.6	65.6	11.1	0.16750	X	X	X		X	X	X	X	X	X	X	X					X	X	X
16	66.6	65.6	11.4	0.16754	X	X	X		X	X	X	X	X	X	X	X			X		X	X	X
17	66.6	65.6	12.7	0.16759	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X
17	66.6	65.5	12.8	0.16761	X	X	X		X	X	X	X	X	X	X	X		X			X	X	X
18	66.6	65.5	14.4	0.16770	X	X	X	X	X	X	X	X	X	X	X	X		X			X	X	X
18	66.6	65.5	14.6	0.16773	X	X	X	X	X	X	X	X	X	X	X	X			X		X	X	X
19	66.6	65.5	16.3	0.16784	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X
19	66.6	65.5	16.3	0.16784	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X
20	66.6	65.4	18.2	0.16797	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X
20	66.6	65.4	18.2	0.16797	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X
21	66.6	65.3	20.1	0.16811	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
21	66.6	65.3	20.1	0.16811	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
22	66.6	65.3	22.0	0.16826	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
22	66.6	65.3	22.0	0.16827	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
23	66.6	65.2	24.0	0.16841	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Vars	sin_fst	slope_fcm	slope_fst	dem_fcm
1				
1				
2				
2				
3				
3				
4				
4				
5				
5				
6				
6				
7				
7				
8				
8				
9				
9				
10				
10				
11				
11				
12	X			
12				
13	X			
13				
14	X			
14	X			
15	X			
15	X			X
16	X			X
16	X			
17	X			X
17	X			X
18	X			X
18	X			X
19	X			X
19	X			X
20	X	X		X
20	X		X	X
21	X	X		X
21	X		X	X
22	X	X	X	X
22	X	X		X
23	X	X	X	X

Best subset results for mixed (Chapter 5)

Response is Ref. canopy

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	2008_b5fcm	2008_b1fcm	2008_b4fst	2008_b1fst	2009b1fst	2008_tc1_fcm	2008_tc2_fcm	2008_tc3_fcm	2008_tc1_fst	2008_tc3_fst	2009_tc2_fcm	2009_tc3_fcm	2009_tc2_fst	2008_ndvi_fst	2009_ndvi_fcm	2009ndvi_fst	2009_temp_fst	aspect_fcm	aspect_fst
1	32.0	31.6	22.0	0.18911								X											
1	23.8	23.3	41.6	0.20019	X																		
2	35.6	34.7	15.3	0.18469					X			X											
2	34.4	33.5	18.2	0.18638								X							X				
3	37.5	36.2	12.8	0.18258								X			X				X				
3	37.1	35.8	13.8	0.18318					X			X										X	
4	39.8	38.1	9.3	0.17982								X			X				X				
4	39.1	37.4	11.0	0.18089								X			X				X			X	
5	43.4	41.4	2.7	0.17505								X			X				X				
5	42.1	40.0	5.9	0.17710								X			X				X				X
6	44.3	41.9	2.4	0.17420								X			X				X				X
6	44.1	41.7	3.0	0.17455								X			X				X				X
7	45.6	42.8	1.5	0.17291								X			X				X				X
7	45.5	42.7	1.7	0.17306		X						X			X				X				X
8	46.4	43.3	1.4	0.17213		X						X			X				X				X
8	46.2	43.1	1.9	0.17245		X						X			X				X				X
9	47.1	43.6	1.7	0.17165		X						X			X				X				X
9	47.1	43.6	1.8	0.17166						X		X			X				X				X
10	48.0	44.1	1.7	0.17088		X			X			X			X				X		X		X
10	48.0	44.1	1.7	0.17091	X							X			X				X	X			X
11	48.8	44.6	1.8	0.17020		X			X			X			X				X		X		X
11	48.6	44.3	2.3	0.17056		X			X			X			X				X		X		X
12	49.2	44.6	2.7	0.17009		X			X			X			X				X		X		X
12	49.2	44.5	2.9	0.17023	X				X			X			X				X	X	X		X
13	49.5	44.5	4.0	0.17023	X				X			X			X				X	X	X		X
13	49.5	44.5	4.0	0.17024					X	X		X			X				X	X	X		X
14	49.8	44.4	5.2	0.17038		X		X	X			X			X			X	X		X		X
14	49.8	44.4	5.3	0.17042		X		X	X			X			X				X	X	X		X
15	50.1	44.3	6.7	0.17065		X		X	X			X			X				X	X	X		X
15	50.0	44.2	6.8	0.17071		X		X	X			X			X	X			X	X	X		X
16	50.3	44.1	8.2	0.17092		X		X	X			X			X				X	X	X		X
16	50.3	44.1	8.2	0.17096		X		X	X			X			X	X			X	X	X		X
17	50.5	43.9	9.7	0.17124		X		X	X			X			X	X			X	X	X		X
17	50.5	43.8	9.7	0.17130	X	X		X	X	X					X				X	X	X		X
18	50.6	43.6	11.4	0.17173	X			X	X	X	X				X	X			X	X	X		X
18	50.6	43.5	11.4	0.17175	X	X		X	X	X					X	X			X	X	X		X
19	50.7	43.2	13.2	0.17224	X	X		X	X	X					X	X		X	X	X	X		X
19	50.7	43.2	13.2	0.17229	X			X	X	X	X				X	X		X	X	X	X		X
20	50.8	42.8	15.1	0.17285	X	X		X	X	X	X				X	X		X	X	X	X		X
20	50.7	42.8	15.1	0.17288	X	X		X	X	X		X			X	X		X	X	X	X		X
21	50.8	42.4	17.0	0.17353	X	X		X	X	X	X			X	X	X		X	X	X	X		X
21	50.8	42.4	17.0	0.17355	X	X		X	X	X	X				X	X		X	X	X	X	X	X

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	2008_b5_fcm	2008_b1_fcm	2008_b4_fst	2008_b1_fst	2009b1_fst	2008_tc1_fcm	2008_tc2_fcm	2008_tc3_fcm	2008_tc1_fst	2008_tc3_fst	2009_tc2_fcm	2009_tc3_fcm	2009_tc2_fst	2008_ndvi_fst	2009_ndvi_fcm	2009ndvi_fst	2009_temp_fst	aspect_fcm	aspect_fst
22	50.8	41.9	19.0	0.17424	X	X		X	X	X	X			X	X	X	X	X	X	X	X		X
22	50.8	41.9	19.0	0.17424	X	X		X	X	X	X			X	X	X		X	X	X	X	X	X
23	50.8	41.4	21.0	0.17495	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X		X
23	50.8	41.4	21.0	0.17495	X	X		X	X	X	X			X	X	X	X	X	X	X	X	X	X
24	50.8	40.9	23.0	0.17567	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
24	50.8	40.9	23.0	0.17567	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X
25	50.8	40.4	25.0	0.17641	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
25	50.8	40.4	25.0	0.17641	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
26	50.8	39.9	27.0	0.17715	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Vars	cos_fcm	cos_fst	sin_fcm	sin_fst	slope_fcm	slope_fst	dem_fcm
1							
1							
2							
2							
3							
3							
4			X				
4							
5	X		X				
5			X				
6			X	X			
6	X		X				
7	X		X	X			
7			X	X			
8	X		X	X			
8			X	X			X
9	X		X	X			X
9	X		X	X			X
10			X	X			X
10	X		X	X			X
11	X		X	X			X
11	X	X	X				X
12	X	X	X	X			X
12	X		X	X			X
13	X	X	X	X			X
13	X	X	X	X			X
14	X	X	X	X			X
14	X	X	X	X			X

15	X	X	X	X	X		X
15	X	X	X	X			X
16	X	X	X	X	X	X	X
16	X	X	X	X	X		X
17	X	X	X	X	X	X	X
17	X	X	X	X	X	X	X
18	X	X	X	X	X	X	X
18	X	X	X	X	X	X	X
19	X	X	X	X	X	X	X
19	X	X	X	X	X	X	X
20	X	X	X	X	X	X	X
20	X	X	X	X	X	X	X
21	X	X	X	X	X	X	X
21	X	X	X	X	X	X	X
22	X	X	X	X	X	X	X
22	X	X	X	X	X	X	X
23	X	X	X	X	X	X	X
23	X	X	X	X	X	X	X
24	X	X	X	X	X	X	X
24	X	X	X	X	X	X	X
25	X	X	X	X	X	X	X
25	X	X	X	X	X	X	X
26	X	X	X	X	X	X	X

Appendix K: Best subset results (Chapter 6)

Best subsets regression results: Woody canopy estimation using disturbance/recovery parameters (Chapter 6)

```
Response is Canopy density

                                                      R
                                                      e
                                                      c
                                                      o
                                                      v
                                                      e
                                                      r
                                                      y R
                                                        s
                                                      t l D R
                                                      i o m m
                                Mallows               m p i a
Vars  R-Sq  R-Sq(adj)        Cp        S  e e n x
   1  44.5       44.1       0.8  0.14271  X
   1   0.5        0.0     107.8  0.19114        X
   2  45.0       44.1       1.7  0.14268  X     X
   2  44.7       43.9       2.3  0.14296  X X
   3  45.2       44.0       3.1  0.14285  X   X X
   3  45.2       44.0       3.1  0.14288  X X   X
   4  45.3       43.6       5.0  0.14335  X X X X
```

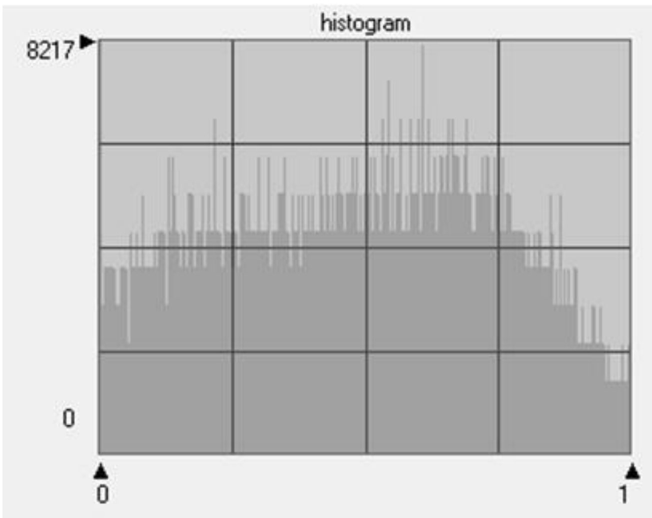
Best subsets regression results: Woody canopy estimation using spectral and terrain variables (Chapter 6)

Response is Canopy density

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	Recovery time	SLOPE	LOW	HIGH	2009_NDVI	2008_NDVI	sin_aspect	cos_aspect	2008_TC1	2008_TC2	2008_TC3	2009_Band5	2009_Band4	2009_TC2	2009_TC3	slope_terrain
1	44.5	44.1	36.4	0.14271	X															
1	20.6	20.0	109.9	0.17073						X										
2	52.4	51.7	14.1	0.13262	X					X										
2	48.4	47.7	26.5	0.13813	X				X											
3	54.1	53.1	11.0	0.13077	X				X	X										
3	54.0	52.9	11.4	0.13097	X					X								X		
4	55.5	54.1	8.8	0.12928	X					X								X		X
4	55.3	54.0	9.2	0.12949	X				X	X										X
5	56.6	55.0	7.3	0.12809	X					X							X	X		X
5	56.4	54.8	7.8	0.12837	X					X				X				X		X
6	57.5	55.5	6.6	0.12730	X					X						X	X	X		X
6	57.3	55.4	7.1	0.12754	X					X							X	X	X	X
7	58.2	55.9	6.5	0.12674	X					X	X	X					X	X		X
7	57.9	55.6	7.4	0.12718	X					X	X		X			X	X	X		
8	58.6	56.0	7.3	0.12662	X			X		X	X	X					X	X		X
8	58.5	55.9	7.5	0.12675	X	X				X	X	X					X	X		X
9	59.0	56.1	8.0	0.12647	X			X		X	X	X		X			X	X		X
9	59.0	56.1	8.0	0.12649	X						X	X	X	X	X		X	X		X
10	59.5	56.3	8.4	0.12615	X			X		X	X	X	X			X	X	X		X
10	59.5	56.3	8.4	0.12618	X			X			X	X	X	X	X		X	X		X
11	60.0	56.5	9.0	0.12595	X	X		X			X	X	X	X	X		X	X		X
11	59.8	56.3	9.4	0.12617	X	X		X		X	X	X	X			X	X	X		X
12	60.2	56.4	10.3	0.12610	X	X		X			X	X	X	X	X	X	X	X		X
12	60.1	56.3	10.5	0.12619	X	X		X			X	X	X	X	X		X	X	X	X
13	60.4	56.2	11.8	0.12632	X	X	X	X			X	X	X	X	X	X	X	X		X
13	60.3	56.2	11.9	0.12642	X	X		X			X	X	X	X	X	X	X	X	X	X
14	60.5	56.0	13.3	0.12662	X	X	X	X			X	X	X	X	X	X	X	X	X	X
14	60.4	55.9	13.7	0.12679	X	X	X	X		X	X	X	X	X	X	X	X	X		X
15	60.6	55.7	15.1	0.12702	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
15	60.6	55.7	15.2	0.12706	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
16	60.6	55.4	17.0	0.12748	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

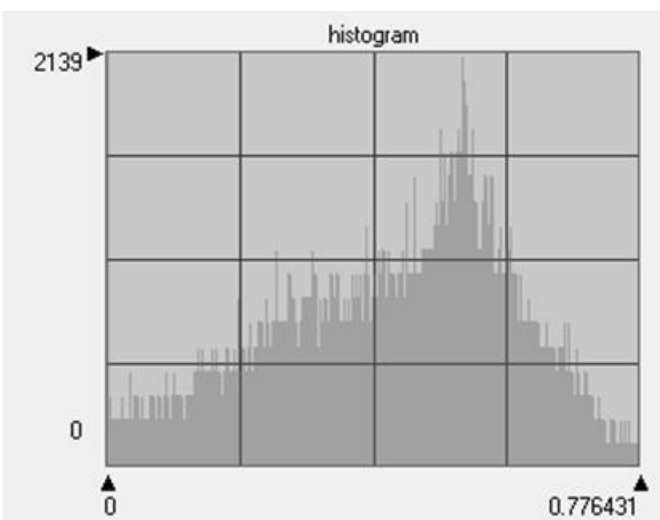
Appendix L: Distributions of Woody Canopy Density and Mining Years:

- Distribution of woody canopy density (horizontal axis) in cloud-free section of reclaimed mine pixels, as estimated using Chapter 5 "mines" model.



Min: 0
Max: 1
Mean: 0.44

- Distribution of woody canopy density (horizontal axis) in cloud-free section of reclaimed mine pixels, as estimated using Chapter 6 model.



Min: 0
Max: 0.776
Mean: 0.424

- Distribution of mining year on cloud-free reclaimed mine pixels, as estimated using Chapter 4 model and used in Chapter 6.

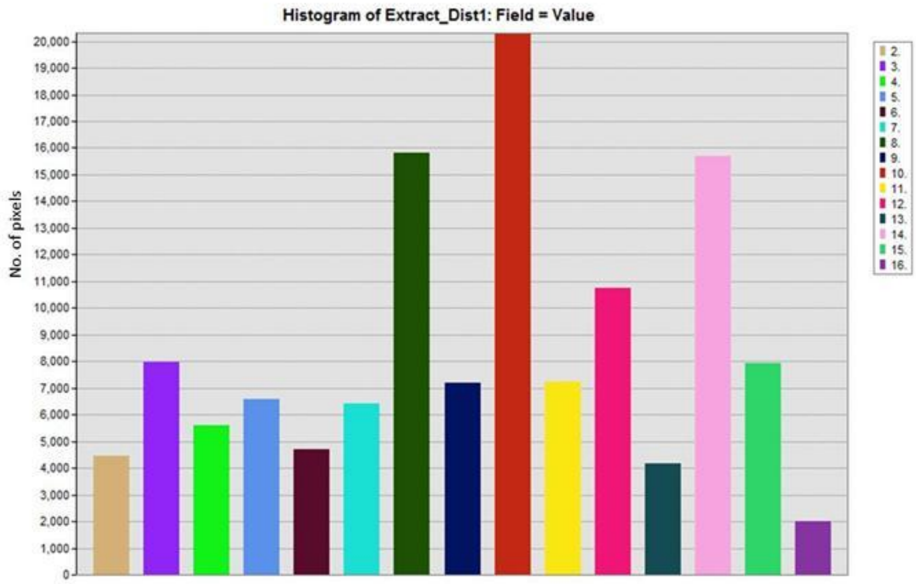


Image dates for choronosequence numbers:

Image Date	Chronosequence Number	Image date	Chronosequence Number
9/17/1984	1	5/19/1998	13
9/20/1985	2	9/3/1999	14
6/19/1986	3	6/9/2000	15
6/6/1987	4	8/15/2001	16
6/8/1988	5	5/22/2002	17
6/11/1989	6	6/2/2003	18
6/30/1990	7	9/24/2004	19
9/21/1991	8	9/11/2005	20
6/6/1993	9	7/12/2006	21
8/28/1994	10	9/17/2007	22
8/31/1995	11	9/3/2008	23
9/5/1997	12		