A MONITORING SYSTEM FOR IDENTIFYING AND RECORDING
LAND CONVERSION IN AGRICULTURAL LANDS
WITH SCS SOIL CAPABILITY CLASSES I - IV

by

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ABSTRACT: This paper discusses the structure, rationale, and application of a monitoring system specifically designed to identify and record conversion of lands with Soil Conservation Service Soil Capability Classes I-IV. Research methodology and design are structured to objectively assess the rates of agricultural land conversion to non-farm uses over a given time interval. A systematic sampling procedure is undertaken in the sample stratum defined by the quarter mile corridor on one or both sides of all established roads in those areas with Class I-IV soils and outside 1980 incorporated city limits. The sampling stratification assumes that conversion of lands with soils in Classes I-IV outside the quarter mile sampling corridor is either negligible or non-existent; that no new roads were constructed on Class I-IV soils outside the sample stratum during the study period; that all Class I-IV lands incorporated into city limits during the study period are converted. Photo-interpretation of aerial photography is the information source used to determine land use status (converted or non-converted) at each of the sample sites. Land conversion is defined by the presence of site modifications which preclude agricultural activities; agricultural fields, farmsteads, and unmodified or natural environments are categorized as non-converted sites.
The proportion of sample sites converted during the study period represents the proportion (area) of the sample population converted and statistically indicates the acreage of Class I-IV lands converted. The accuracy of the resulting land conversion data generated in the Yamhill study tends to support the efficacy and utility of the monitoring system. The study area has experienced limited conversion (range of 206 - 303 acres annually) in Class I-IV lands, and as expected, the occurrence of sample site conversions is directly influenced by expanding city limits boundaries eliminating high conversion areas from analysis as well as distance from primary urban centers.

INTRODUCTION

In response to increasing rates of conversion of agricultural land to non-farm uses, the State of Oregon has established laws that require local government agencies to provide for the preservation and maintenance of agricultural lands in their productive farm status. Yet, currently no monitoring system or evaluation process is regularly employed to objectively assess the current rates and acreage of agricultural land conversion or to evaluate the efficacy of state and local agricultural land use planning programs.

Purpose and Objectives

The purpose of this study is to develop and test a monitoring system than can identify and record land conversion on
agricultural lands of Soil Conservation Service (SCS) Soil Capability Classes I-IV. The objectives of the monitoring system are that it be an effective and comprehensive but relatively simple and inexpensive procedure that can be implemented statewide and that can be easily updated for subsequent monitoring and follow up. Data base inputs are readily available and future (update) data bases are relatively accessible. Existing data and materials comprise the majority of information input needs: road maps, soils maps, incorporated city limits maps, aerial photography, county records and other readily accessible information sources. These primary data inputs are supplemented by ground truth visits.

**Assumptions**

The monitoring system employs a systematic dot grid sampling procedure utilizing integrated map bases and multiple dates of aerial photography. The following are assumptions that are incorporated into the design of this study:

1.) Land conversion outside of the quarter mile road corridor sampling stratum was either negligible or non-existent.

2.) No new roads on Class I-IV soils were constructed outside of the original sample stratum during the study period.

3.) All land with Class I-IV soils incorporated into city limits during the study period were converted (this total incorporated acreage is added to the base converted acreage figures derived from the sampling).
4.) All areas within the SCS Soil Capability Class I-IV boundaries (as defined by the SCS Yamhill County General Soil Map for farm crops) are accurately mapped for the purposes of this study.

5.) Conversions in transitional stages at the date of photography were either apparent or considered non-existent.

6.) All conversions or modifications are visible on the aerial photography and unobscured from photointerpretation.

7.) Agricultural support facilities and industries (directly farm based) can be accurately identified and excluded from being categorized as converted to non-farm uses.

**Defining Conversion**

From the initial phases of designing the monitoring system, it is taken into consideration that accurately defining and identifying land conversion is the critical factor in determining the success of such a study. This monitoring system determines conversion by identifying conditions of non-conversion. Non-conversion is defined by active agricultural practices as well as by unmodified or natural environments. Sample sites representing other types of modifications (not directly related to agriculture) are designated as converted.

Since a number of contributing factors and surrounding conditions must be taken into account while analyzing a sample site, photointerpretation decision criteria are required from the beginning. A farmstead is a dwelling unit inhabited by
persons engaged in agriculture, and as such, does not constitute land conversion. In this study, a farmstead is defined as a rural dwelling unit with two or more outbuildings (for agricultural equipment and activities).\(^3\) Other factors taken into consideration while identifying a farmstead include: 1.) proximity to agricultural activities, 2.) accessibility to adjacent agricultural fields, 3.) lot size and dimensions, 4.) condition of improvement of surrounding land on the lot, 5.) proximity to other dwelling units (especially new ones), and 6.) distance from urban centers.

All sites in their natural state, unmodified by man, are categorized as being non-converted. Included in this category are forests, riparian vegetation, cleared but uncommitted land such as clearcuts, wetlands, meadows, natural or unimproved pasture, water bodies, gravel bars, rock outcrops and other land features that often are not specifically included in SCS Soil Capability Classes I-IV but rather are anomalies in the general mapping units. If such anomalous land features within the sample stratum are selected by the systematic dot grid to be sample sites, these sites should be included and categorized as non-converted.

In some site analysis conditions, it is necessary to look beyond the immediate sample point. In circumstances when conversion is suspected but inconclusive, the five acres immediately surrounding the sample point are also included in the analysis. If a sample point is located on a side road or driveway leading exclusively to a non-farm dwelling unit, then that sample site
constitutes conversion. Problems also arise when sample points are located in large lots which are predominantly unmodified; in such circumstances it is important to examine and analyze all of the area within the lot because another portion of this lot may be converted to non-farm uses and, therefore, the entire lot, including the sample point, is converted.

Area Description

Yamhill County is the area selected for demonstration of the land conversion monitoring system. Selection of Yamhill County is based upon a variety of reasons which include its agricultural characteristics and population growth patterns as well as the availability of a Soil Survey Manual, county soils maps and Soil and Water Conservation District publications. Another noteworthy reason is the amiable and helpful County Planning staff members. In addition, the county does have an acknowledged comprehensive plan which includes extensive agricultural land use provisions.

Yamhill County is located on the west side of the lower middle part of the Willamette Valley and is bordered by Washington County to the north, the Willamette River along Marion County and Clackamas County to the east, Polk County to the south and Tillamook County to the west. Total area of the county is 453,760 acres (709 square miles) of which 240,210 acres (375 square miles) are in SCS Soil Capability Classes I-IV. Incorporated city limits account for 12,400 acres
(19.5 square miles) with 1,059 acres having been incorporated during the study period. Almost all lands within the incorporated city limits are in Class I-IV soils.

The landscape of the county consists of flat agricultural lands (such as the Dayton Prairie) laced with creeks and rivers in the middle and eastern areas of the county, steeply protruding hills (Red Hills and Amity Hills) in the northeast and southeast, and the Coast Range mountains to the west. Soils in the county are quite diverse, and many are well known for their high fertility and productivity. Soil types vary from steeply sloping to nearly level, excessively to poorly drained, deep to shallow profiles, and very productive to very poor or nearly useless. The climate is Pacific Maritime Sub-Tropical with an average annual precipitation of 43.55 inches and average temperatures of 38.4°F in January and 65.2°F in July.

Yamhill County has a strong and diverse economic base. Agriculture is of primary importance along with lumbering, education, mobile home production, wood products, pulp and paper products, steel manufacturing, plastic products and other light manufacturing and small industrial plants. Horticultural crops (row crops, vineyards, orchards, and specialty crops) and grains along with livestock and poultry production comprise the bulk of agricultural activities. Of interest to note is that Yamhill County has recently become Oregon's leader in the number of wineries and vineyard acreage.
Population dynamics in Yamhill County are variable yet not extreme nor unpredictable. The population in incorporated areas has increased at a steady rate from 1940 to 1978, while the percentage of county population residing in unincorporated areas has declined to about thirty percent of the total population in 1978 from about fifty-four percent in 1940. Population growth in the urban areas accounts for most of the overall growth, and those cities closest to major highways will probably experience the greatest growth in the future. The 1980 county population of 54,318 has increased by approximately 10,000 persons between 1974 and 1980, of which 2,147 persons have settled outside of incorporated city limits.
METHODOLOGY

The methods of data assembly and analysis used in the study are numerous, diverse, and interrelated. A methodical step by step procedure is required because the operation of a latter step is contingent upon the execution and results of the one preceding it. The identifying, organizing, and integrating of raw data are the interactions of the initial phases of research while intensive analysis, computations, and results follow.

Map Bases

The first phases of the study require the assembly and integration of numerous base maps. Requirements of these maps are to supply basic information pertaining to roads, soils, and current city limits boundaries. Salient information pertinent to the study is extracted from the maps and integrated into a new, single working map base. Assemblage of this new map base is requisite for defining the sample population, determining the number and spacing of sample sites, identifying those aerial photographs that are needed, and numerous other applications. A minimum of five different maps are required, and the more maps one has available for use the better. A general county soils map, a county road map, an updated incorporated city limits map, and flight maps for each date of aerial photography are the minimum number of maps required. Other map bases such as topographic maps, detailed soil survey
maps, tax assessors maps, county zoning maps, and other similar map bases can also be of use.

Aerial Photography

National Aeronautics and Space Administration (NASA) high altitude color infrared aerial photography is the information source used to determine the land use or conversion status of the study period. Fourteen color infrared positive transparencym aerial photographs at a scale of 1:63,360 or one inch to the mile were used in the initial site analyses. These photographs were taken by NASA on June 30, 1980 and are of a nine inch format. The initial analysis of all sample sites was done on this most recent imagery.

To determine the status of the sample sites at the beginning of the study period, aerial photographs taken by NASA on September 24, 1974 are also used. These are five color infrared positive transparency aerial photographs at a scale of 1:130,000 or two miles to the inch and in a nine inch format. Only those sample sites found to be converted in 1980 are examined on the 1974 photography to determine whether or not the sites were converted prior to the study. If so, they do not represent conversion during the study period. Those sites converted in 1980 but not showing signs of modification in the 1974 imagery are counted as having been converted during the study period.

Circumstances in other similar studies might require the
use of other available aerial photography. Some study areas may not have the necessary high altitude color infrared aerial photography coverage or the dates of available high altitude imagery may not correspond to the study period dates. Various dates and scales of aerial photography are available from numerous agencies including the Environmental Remote Sensing Applications Lab, the Oregon Departments of Forestry and Transportation, the Soil Conservation Service, the Agricultural Stabilization and Crop Service, and numerous local government agencies as well as private aerial photography businesses. The Oregon Department of Forestry compiles an annual statewide index of all private and public aerial photography missions, This noteworthy index should be consulted when designing an aerial photography based study.

Equipment and Materials

As previously noted, this monitoring system is designed so as to require a minimum of technical equipment. Equipment utilized in the study includes a Kail projector used to integrate all the map bases to a common working scale; a digitized planimeter to measure road lengths and sample stratum area (a simple, manual planimeter will do), an Old Delft scanning stereoscope for photointerpretation, and a light table and hand lens also for photointerpretation. All of the above mentioned equipment was available for my use at Oregon State University located in either the Environmental Remote Sensing
Drafting equipment and supplies used in the study are widely available and generally inexpensive. Technical drafting pens were used for drafting (roads, road corridors, city limits boundaries, etc.) on clear mylar overlays mounted on top of the aerial photography. Various marking pens and pencils were used on paper print maps and on frosted acetate transparent overlays placed on top of base maps. Drafting tape one-half inch in width was used as a mask to represent the road corridors on mylar overlays. All of the above-mentioned materials are widely used and represent minimal costs.

**Statistical Procedures**

In order to develop a monitoring system that is both inexpensive and expedient to apply, it is necessary to employ a statistical sampling procedure as opposed to a more time consuming comprehensive inventory. From a statistical perspective, the phenomenon which is being measured, namely the acreage of annually or periodically converted land in Soil Capability Classes I-IV, is a minute proportion (less than one-half of one percent) of the entire population (all Class I-IV soils) and, thus the sampling strategy is one of sampling for a "rare population."

**A History of Sampling in Land Use Surveys**

Statistical sampling procedures are not new to land use
surveys. As early as 1924, Carl Sauer advocated the use of statistical sampling methods in quantitative land use studies using a systematic approach. A sampling procedure would require less energy and time inputs yet "supply an adequate, systematic body of significant data out of which generalizations may shape themselves with increasing diversity as the source material grows in amount." The U.S. National Inventory of Soil and Water Conservation Needs (1961) was based upon a two percent area sampling rate allowing the entire country to be covered in a uniform survey. More recently, Brian Berry used statistical analysis to develop a degree of association between a land use category and an aspect of the natural environment based upon frequencies obtained by a point sampling design. Berry concluded that sampling procedures facilitate the interpretation of land use patterns through spatial associations. The monitoring system for identifying and recording land conversion follows this established approach to land use studies while being designed to a specific application.

**Components of the Statistical Formula**

A systematic dot grid sampling regime is employed in the sample population defined by the stratified quarter mile corridor on one or both sides of all roads located on Class I-IV soils. The primary data required to determine the sample size (number of sample sites) and thus initiate the sampling
procedure are: 1.) the size of the sample population (area of land within the sample stratum), 2.) the error factor or desired size (width) of the confidence interval of the final results, and 3.) the "p value"--the best available estimate of that proportion of the population that is being researched (in this case, the number of Class I-IV acres converted in the study period).

The p value, error factor, and sample population size are all entered into a formula that yields an initial sample size estimate (see Appendices A & B). This estimate represents the minimum number of required sample sites but must still be adjusted. As a safety factor, the minimum sample size is adjusted or increased by a percentage equal to an estimate of the proportion of the sample population that will have already been converted at the beginning of the study period (see Appendix B). This adjustment is done to reduce the possible error that would occur if too few samples were allocated. Such a situation could possibly occur if a significant number of sample sites were located on previously developed lots which are subsequently insensitive to change during the study period, thus cannot measure conversion. The statistical formulas, specific measurements generated in the study, and discussion of statistical considerations are included in the appendices.

**Dot Grids for Locating Sample Sites**

A systematic dot grid is used for locating the sample sites in the sample stratum. The sample sites are spaced approximately
one-third of a mile apart as determined by the method described in the appendix (see Appendix E). In order to arrive at a nearly equal spacing or distance between all points in the dot grid, a hexagonal based grid pattern was developed with dots (points) located at the centroid and vertices. Care was taken to offset the dot grid overlay in such a manner so that the sample points did not intentionally align in a direct north-south or east-west orientation thus avoiding the risk (bias) of locating the sample points along ownership boundaries, highways, right of ways, or other possible culturally determined features and land uses. Also worthy of note is that the sample points (sites) were located in the sample stratum on the road corridor overlay without using the aerial photography, thus avoiding any bias as to where the sample points fall.

Two particular decision criteria for locating the sample points were necessary. While locating sample sites on the road corridor overlay, those points landing on the boundary line of the corridor are relocated just inside the boundaries. In those circumstances when the sample point falls on the dividing line between two dissimilar land use parcels, the focus (and analysis) is on that parcel where half or more of the sample point falls. These decision criteria were determined early in the study to assure consistency and precision.

Some researchers have questioned the validity of considering each sample point (site) of a systematic grid as a truly random, independent observation. One group of researchers claim that
each positioning of a systematic dot grid constitutes only one sample regardless of how many sample points are contained in the grid. Another claim among some researchers is that a single dot grid trial is inadequate for determination of an estimate of error (width of confidence interval). After review and consideration of the various claims mentioned above, the systematic dot grid sampling approach is still considered to be the most effective and appropriate sampling strategy and remains as such until the above mentioned claims are conventionally substantiated and are then generally accepted by professional statisticians.

DESCRIPTION OF THE RESEARCH PROCEDURE

A review of the various steps involved in the actual procedure is now presented. This review is presented to coordinate, reinforce, and clarify the material presented thus far. The order in which the various steps of the methodology are executed is critical to the success of the study and, therefore, warrants a succinct review which follows.

Compiling A Single, Unified Base Map

Integration of all the map information into a single, unified base map is the initial step. General soils map boundaries of those soils within SCS Soil Capability Classes I-IV are transferred to a county road map (the new base map). Updated incorporated city limits boundaries also must be delineated on
the new base map because these areas are excluded from the sampling.

**Defining the Roads Within the Sample Stratum Corridor**

Those roads with either one or both side corridors composed of Class I-IV soils are identified and marked on the base map. Road lengths with only one side corridor composed of Class I-IV soils should be noted as such by marking the excluded area. Where an intersection of these roads occurs, omit one of the intersecting road lengths for a quarter mile on both sides of the intersection. This is done to avoid duplication of measurement of the sample stratum area represented by the intersection as described in the following step.

**FIGURE 2. UNIFIED MAP BASE**
Estimation of Sample Population Size

Now that the roads in the sample stratum have been identified, the road lengths need to be measured. To estimate sample population size, the total length of roads with eligible sample stratum corridors on both sides is multiplied by 320 acres per mile, whereas the total length of roads with an eligible sample stratum corridor on only one side is multiplied by 160 acres per mile. The two area measurements are summed, and the resulting total represents an initial estimate of the sample population size or area. Care should be taken not to over-measure (estimate) the sample area contained in road intersections—this error is avoided by omitting one of the intersecting road lengths within a quarter mile of the intersection as mentioned above. Care should also be exercised when measuring those roads with a sample stratum corridor on only one side so as not to confuse these roads with those having sample stratum corridors on both sides.

Determining the Sample Size

The sample size or required minimum number of sample points can be computed using the formula found in the appendices (See Appendices A, B & C). Input data required to determine the sample size are discussed in an earlier section titled "Components of the Statistical Formula." The spacing of the sample points on the dot grid overlay can also be determined using the procedure listed in the appendix (See Appendix E).
Preparations for Site Analysis Using Aerial Photography

Those road corridors in the sample stratum need to be transferred from the base map to a transparent mylar overlay on each of the designated work frames of the most recent aerial photography. The sample points are then located via the dot grid overlay, and finally the designated sample points are counted to assure the required minimum number of samples.

Defining the Sample Stratum Corridor Boundaries on the Photo Overlays

The road corridor boundaries or those boundaries which define the sample stratum are determined by a fairly simple procedure. Mounting transparent overlays on the 1980 photos is the first step. Those roads in the sample stratum (as previously defined on the base map) are then marked on the overlay taking care to note when only one side of a road is included in the stratum (this can be done by red lining the ineligible side). Drafting tape of a width representing the dimensions of the corridors on both sides of the road is then centered along the road lengths with only half the width of the tape being used in those circumstances when only one side of a road is in the stratum (See Appendix F). This tape represents the sample stratum corridors and constitutes a mask of the corridors. Another transparent overlay is then placed over the sample stratum corridor mask overlay, and the outside boundaries of the sample stratum (as defined by the mask) are outlined with care taken to mask any
ineligible areas that may have been included in the larger outlined stratum boundaries (See Appendix F). The exact total area contained in all of the newly defined (outlined) sample stratum corridors will need to be carefully measured for input into the final analysis.

**Locating the Sample Points in the Sample Stratum**

Now that the sample stratum corridor boundaries have been defined, the sample points can be located in the stratum using the dot grid overlay. Locating the sample points is accomplished by placing the sample stratum corridor boundaries overlay on top of the dot grid overlay without using the aerial photography so as to avoid any bias (See Appendix F). All of the dot grid points falling within the sample stratum boundaries are marked, and those sample points falling on the boundary line itself are relocated just inside the boundary. This adjustment of sample points falling on the boundary line helps to correct for possible locational errors occurring when locating the stratum corridor boundary.

After all of the sample points have been located on all of the overlays, it is then necessary to count all of the located sample points to be sure that the minimum number of required samples has been accounted for. A total of 1,429 sample points are located in the sample stratum in the Yamhill study, an amount much larger than the minimum required (See Appendix B).
The Analysis of Sample Sites

Analysis of the sample points is accomplished in a multistage process. This multistage procedure is employed to maximize work efficiency by expeditiously eliminating those sample sites which are obviously unconverted thus allowing more time for indepth analysis of those more difficult or obscure sites. Sample site analysis is focused on the specific location of the sample point. Occasionally, a larger five-acre area surrounding the sample point is inspected in those inconclusive cases where site conversion is suspected but uncertain. An approach such as this facilitates an analysis which is both quantitative and qualitative.

Primary Analysis

This first step involves a quick manual analysis. Each sample point is inspected without the aid of a stereoscope, and all of those sites that are clearly and unequivocally non-converted or unmodified are marked as such and disregarded. All of those sites which show evidence of conversion, and all of those which are under any suspicion whatsoever of being converted, are noted as such by drawing a circle equivalent to five acres in size around that sample point. These circled sites warrant more sensitive, secondary analysis. In the Yamhill study, all but one-half of one percent of all the sample sites were determined to be non-converted and, therefore, eliminated in this primary stage of analysis. This left 45 sites as possible conversions.
Secondary Analysis

Those sample sites concluded to be converted or suspected of conversion (noted as such by the five-acre circle surrounding them) are examined in stereo. Stereoviewing in magnification results in increased feature detail allowing improved accuracy of photointerpretation and analysis. Now in stereo with increased perception, those suspected sites that are found to be definitely engaged in agriculture or are truly in a natural, unmodified condition are classified as non-converted and consequently crossed out, eliminated and disregarded. Five out of forty-five known or suspected sites were eliminated in this step in the Yamhill study.
Remainder sample sites that are interpreted as being definitely converted or highly suspect (still inconclusive) of being converted after the secondary analysis are then further identified and assigned an identification number. A brief physical description of each of these sites and their immediate surroundings should be noted and recorded. Each of these numbered sites is then located and marked on a county road map to facilitate further analysis. In the Yamhill county study, forty sites were numbered, recorded and located on the road map.
Determining the Date of Conversion

Determination of the exact date of site conversion would be useful information yet not really necessary for the purposes of this monitoring system. This study attempts to determine the amount of Class I-IV land area converted over a given time period and, therefore, determining whether a site is converted before or during the study period is all that is necessary. In order to accomplish this, each of the numbered sites is located on the earlier date (1974) of photography, and a circle is drawn around each site regardless of modification status at that date. These circled sites are then examined to
determine whether or not the feature of conversion or modification is present. If the feature of conversion is not present, then the site is concluded to have been converted during the study period. Locational control and accuracy at this stage is critical so as to be certain that the same, exact sample site (point) is being analyzed on both dates of imagery. All sample points found converted in the study period are recorded as such while all other sites are recorded as being converted prior to the study period. This data is then input into a "conversion acreage estimator" statistical formula to determine the number of acres converted during the study period (See Appendices A & C).

Verification of Findings

All numbered sites have been located on a county road map in order that the analyses can be verified by ground checks, consulting various county records or knowledgeable persons. County planning departments, tax assessors, engineering departments, and a variety of other agencies have recorded information in those cases where verification of analysis is necessary.

In this study, about thirteen percent or five of the forty converted sites were significantly uncertain so as to require supplemental data for verification. Personnel (the Senior Planners) at the Yamhill County Planning Department were able to recognize each of the five questionable sites on the aerial photography and verify the analyses at those sites. Those five sites were ground checked as well.
RESULTS

The results of the study indicate that the Yamhill study area has experienced limited Class I-IV land conversion during the study period. The identified and recorded conversion is largely clustered around the city of Newberg; these results were no surprise to those familiar with the area. In general, the occurrence of land conversion found in the study is strongly influenced by the distance from an urban center.

A total of 1,429 sample sites were analyzed. Of 1,429 sample sites, 1,349 or 94.4 percent of the total are either involved in agriculture or are in their natural, unmodified state. Forty of the sample sites or about 2.8 percent of the total are located on established highways and roads and as such provided little interpretive insight. The remaining forty sites are converted with 33 (2.3 percent of the total sites and 82.5 percent of the converted sites) being converted prior to the beginning of the study. Seven of the forty converted sites (0.5 percent of the total sites and 17.5 percent of the converted sites) were converted during the study period—the six-year interval between 1974 to 1980.

The proportion of sample sites converted during the study period indicates the amount of Class I-IV land converted during the same time span. By applying the percentage of converted sample sites (0.5%) to the total number of acres within the sample stratum road corridor (90,644 acres), the total number of converted acres outside city limits is calculated to be 468, with a possible range of 178 - 758 acres. Together with the area
incorporated into city limits during the study period (1,059 acres), a total acreage range of 1,237 to 1,818 acres of SCS Soil Capability Classes I-IV land was converted during the study period. Averaged out on an annual basis, this represents a range of 206 to 303 acres of Class I-IV land converted each year. This average annual conversion rate represents a maximum of 0.13 percent of all Class I-IV land area in the county, a relatively small percentage figure on a day to day basis. However, over a longer period it could prove to be more significant. Of interest to note is that 17.5 percent of all converted sites in the study, exclusive of established roads and highways, experienced that change in the six-year period between 1974-1980.

Sample sites located on established roads and highways are treated as a unique group. These sites qualify as converted sites by the stated definitions but are not treated or recorded as such because they are totally insensitive to conversion or modification. The presence of an established road is the criterion used to define and identify the sample stratum corridor and, therefore, roads (and sample sites located on them) are not randomly present in the sample stratum. In order to avoid bias in the analyses, sample sites located on main roads and highways are separately grouped and segregated from other types of converted sites.
RECOMMENDATIONS

In retrospect, a number of ideas and recommendations come to mind to suggest to anyone who might want to employ the above described investigative approach and techniques. It is of interest to note that seventy-two percent of all the time spent on the project occurred in the initial set up stages, whereas the actual site analyses represent twenty-eight percent of the time inputs. With this in mind, I would suggest that the relative sample size be increased at least two-fold. This increase in the sample rate would result if a smaller error estimate was assumed, perhaps a 0.20 estimate rather than the 0.33 estimate.

Other sampling possibilities include using two different sampling efforts to get an indicator of consistency of results. This multiple approach can be accomplished by two different random placements of the same dot grid overlay on two sets of a sample stratum overlay. It might also be useful to utilize two different dot grid density overlays to determine whether dot grid density influences sampling results. Also, each sample site could be categorized according to a simple classification scheme resulting in a more comprehensive and qualitative land use survey. More exact soils conversion data could be obtained by simply recording what class of soil (Classes I-IV) is at each converted site, resulting in conversion data for each class of soils.

Finally, one might want to conduct more specialized analysis around urban areas. Changes in urban population and incorporated city limits area could be coupled with surrounding vicinity land
conversion data from the sampling operations to determine possible interactions or relationships. These findings could prove to be invaluable information to planners in understanding the results of different approaches to urban/rural planning.

A myriad of potential sample design modifications and improvements exist—the basic design and strategy in this study appears feasible, pending further application and refinement.

SUMMARY

The intent of this research effort was to develop a simple and inexpensive land use data gathering and analysis procedure that could have widespread applicability and could be employed by land use planners in agricultural land use planning programs. A systematic sampling procedure is undertaken in the sample stratum defined by the quarter mile corridor on one or both sides of all established roads in those areas with Class I-IV soils and outside current incorporated city limits. Photointerpretation of multiple dates of aerial photography is the information source to determine sample site land use status at the beginning and end of the study period. Procedures, methodology, decision criteria and analytical techniques are established in the initial phases of the study and employed consistently. The resulting analyses yield data findings which support the utility and integrity of the monitoring system approach and have real value to those involved in agricultural land use planning programs. Refinements and adaptations can be applied to the research methodology to allow it to be effective and applicable in a wide range of specific studies and inquiries.
FOOTNOTES


3. Personal communication with an official of the Mapping Section, Oregon State Highway Division. This is the definition of a farm unit used by the State Highway Division in their preparation of County General Highway Maps.


5. Ibid.; personal communication with Yamhill County Planning Department, February, 1981.


7. Ibid., p. 250.


11. Ibid., p. 1.

12. Ibid., p. 2.


14. Ibid., p. 32.


APPENDIX A

STATISTICAL FORMULA

Initial Sample Size Estimate

\[ n = \frac{t^2}{d^2} p(1-p) \]

- \( n = \) Sample size or number of samples
- \( t = 1.645 \) for a 90% confidence interval
- \( d = \) Desired size of confidence interval / error estimate
- \( p = \) p value estimate or proportion estimate

Estimator + 90% Confidence Limit

\[
\text{Acreage converted} = N \hat{p} + t N \sqrt{\hat{p}(1-\hat{p})/n}
\]
during study period

- \( N = \) Sample population size (area) in acres
- \( \hat{p} = \) Number of sites converted during study period
- \( \) Total number sample sites - Those converted in beginning of study period = \( n \)
- \( t = \) 90% confidence interval = 1.645
- \( n = \) Total number sample sites - Those converted in beginning of study period
APPENDIX B

STATISTICAL FORMULA

Determining the Sample Size

Initial Sample Size Estimate

\[ n' = \frac{t^2}{d^2} \cdot p(1-p) \]

\[ t = 1.645 = 90\% \text{ confidence interval} \]
\[ d = \frac{1}{3} p = 0.33 \times 0.0481 = 0.0160 \]

\[ \frac{444 \text{ Permits x 5 acres converted per permit}}{3 \text{-year time interval}} = 740 \text{ Converted acres} \]
\[ \frac{2220 \text{ Acres}}{3 \text{ years}} = 740 \text{ Converted acres} \]
\[ \frac{p = 0.04813 = 6 \text{ Years of study x 740 acres = 4440 converted acres}}{\text{Year}} \]

\[ 4440 \text{ Acres Converted} \]
\[ 92,233 \text{ Acres estimated in sample stratum} = 0.048138 \]

\[ n' = 484 \]

Sample Size Adjustment

In order to assure that the minimum required number of sample sites are analyzed, the sample size is increased by the proportion of the sample population estimated to be converted at the beginning of the study period. A maximum of 15 percent
of the sample population is estimated to be converted at the beginning of the study period, so the initial sample size estimate is divided by 0.85.

\[
n' = \frac{484}{0.85} = 570 \text{ minimum sample size}
\]

A sample size of 570 equals a dot grid spacing frequency of one-half of one mile apart (see Appendix D), but in the study it was decided to increase the frequency by reducing the spacing to one third of one mile. This adjustment resulted in 1,429 dot sample sites being included in the sample population.
APPENDIX C

STATISTICAL FORMULA

Conversion Acreage Estimator and 90% Confidence Limit

\[ \text{Converted Acreage} = N \hat{p} \pm 1.645 \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \]

\[ N = 90,644 \quad \text{As determined by measuring area in sample} \]
\[ \text{corridors on the imagery - Final measurement} \]

\[ \hat{p} = \frac{7}{1429 - 73} = \frac{7}{1356} = 0.00516 \]

\[ n = 1356 \]

468 \pm 290 \quad \text{Range of acres converted over study period}
178 - 758 \quad \text{Range of acres converted over study period}
+ 1059 \quad \text{Acres incorporated into city limits during study period}
1237 - 1817 \quad \text{Range of acres converted over study period}
\quad + \text{incorporated area} \quad \text{(6 years)}
206 - 303 \quad \text{Acres converted per year - FINAL RESULT}
The generation of the p value or estimated proportion can be a difficult task. This is especially true in a study such as this one where no single source of information indicating this value can be found. Consequently, one must evaluate indirect or index information that will substitute as an effective estimate of p.

In this circumstance, information was obtained from a map titled "Land Use Changes 1974-1977" found in the Natural Resource Conservation Plan 1980-1985, prepared by the Yamhill Soil and Water Conservation District and published in 1979. This map listed the number of permits (partitions, lot size variances, conditional use permits, and subdivisions) issued in each section (square mile) over a given time period (3 years). General soils map boundaries (for crop suitability) are transferred on to the permit map to yield a rough estimate of the number of permits granted in those areas with SCS Soil Capability Classes I-IV. Multiplying the number of permits granted by the estimated number of acres typically converted per permit issued provides a rough indicator of the p value.

It is important to note that not all permits granted are acted upon, that not all development consumes (converts) the same amount of land, and that some of the permits issued may have been for the construction of farmsteads and, therefore, would not constitute land conversion. The assumed acreage
converted per permit issued is an important number in the p value estimate, and if the assumed acreage converted per permit estimate is grossly inaccurate, it can be very misleading throughout the study.
APPENDIX E

STATISTICAL FORMULA

Dot Spacing Method

Method to Determine Spacing of Dots (sample sites) in Order to Get Required Number of Sample Sites Into the Sample Stratum

STEP A: Take sample population size, aggregate it into a hypothetical square and determine length of a side.

STEP B: Take the square root ($\sqrt{\cdot}$) of the total number of sample points. The resulting number equals the number of sample points located on a side if in a square.

STEP C: Distance needed between points on a side is equal to the square side length divided by the number of points on a side.

STEP D: Make a grid with dots spaced at distance above.
STEP A: 92,233 acres of class I-IV land in sample stratum divided by 640 acres per square mile = 144 sq. miles = a square 12 miles on each side = 12 miles x 5282 feet per mile = 63,385 feet on a side.

STEP B: Square root of 570 sites = 24 points on a side

STEP C: 63,385 divided by 24 = 2,636 feet between points on a side = 0.499 miles or 0.5 miles.

NOTE: In the Yamhill County study, it was decided to space the dots 1/3 mile apart which resulted in 1,429 sample sites.
GENERAL SOILS MAP OVERLAY WITH CAPABILITY CLASS I-IV SOILS GROUPED TO DEFINE THE POPULATION (ALL CLASS I-IV SOILS)

SAMPLE STRATUM MASK—TAPE CENTERED ALONG ROADS IN CLASS I-IV SOILS REPRESENTS THE SAMPLE STRATUM
SAMPLE STRATUM MASK MOUNTED ON AERIAL PHOTOGRAPHY

SAMPLE STRATUM BOUNDARIES OVERLAY WITH LOCATED AND ANALYZED SAMPLE SITES.  •  REPRESENTS SUSPECTED CONVERTED SITE ELIMINATED AFTER SECOND CUT.  ○  REPRESENTS VERIFIED CONVERTED SITE.
LOCATION OF CONVERTED SAMPLE SITES

• DENOTES CONVERTED SITE

○ DENOTES SITE CONVERTED DURING STUDY PERIOD