Application of Roadside Transect Survey to Identify and Inventory Agricultural Conservation Practices for the Bay Model

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Tetra Tech Assessment

An assessment of roadside transect survey accuracy was performed to determine the suitability of roadside transect surveys to identify agricultural conservation practices for credit in the Chesapeake Bay Program (CBP) partnership's watershed model. The assessment combined the findings from a literature search and a detailed evaluation of the strengths and weaknesses of selected metrics.

Literature

- Three publications provided evidence of the accuracy of roadside transect surveys for cropland residue
  - Roberts and Coleman (1988)
  - Thoma et al. (2004)
  - Zheng et al. (2013)

Roberts and Coleman 1988

Accuracy of Residue Cover Estimation

Residue Category (%)	Total Fields	Fields Correct	Percent Correctly Classified[1]	90% Confidence Interval[2]
0-15	725	706	97	96%-98%
15-30	108	99	92	86%-96%
30-45	62	59	95	88%-99%
45-75	45	41	91	81%-97%
75-100	6	6	100	61%-100%
All	946	911	96	95%-97%

[1] This is equivalent to the Proportion Correct (PC) metric.

[2] 90% confidence interval using exact binomial distribution.

Combined roadside survey with on-site survey over 10,000 fields.
n determined via multinomial distribution assumption.

Thoma et al. 2004

Average Accuracy of the Tillage Roadside Transect Survey
Visual Classifications of Crop Residue Cover
Conducted by Agency Personnel in Three Minnesota Counties

Number of Categories	Corn + Bean n = 161[1]	Corn n = 100	Bean n = 53
	% Fields Correctly Classified		
5	49	50	45
3	74	70	77
2	74	70	77

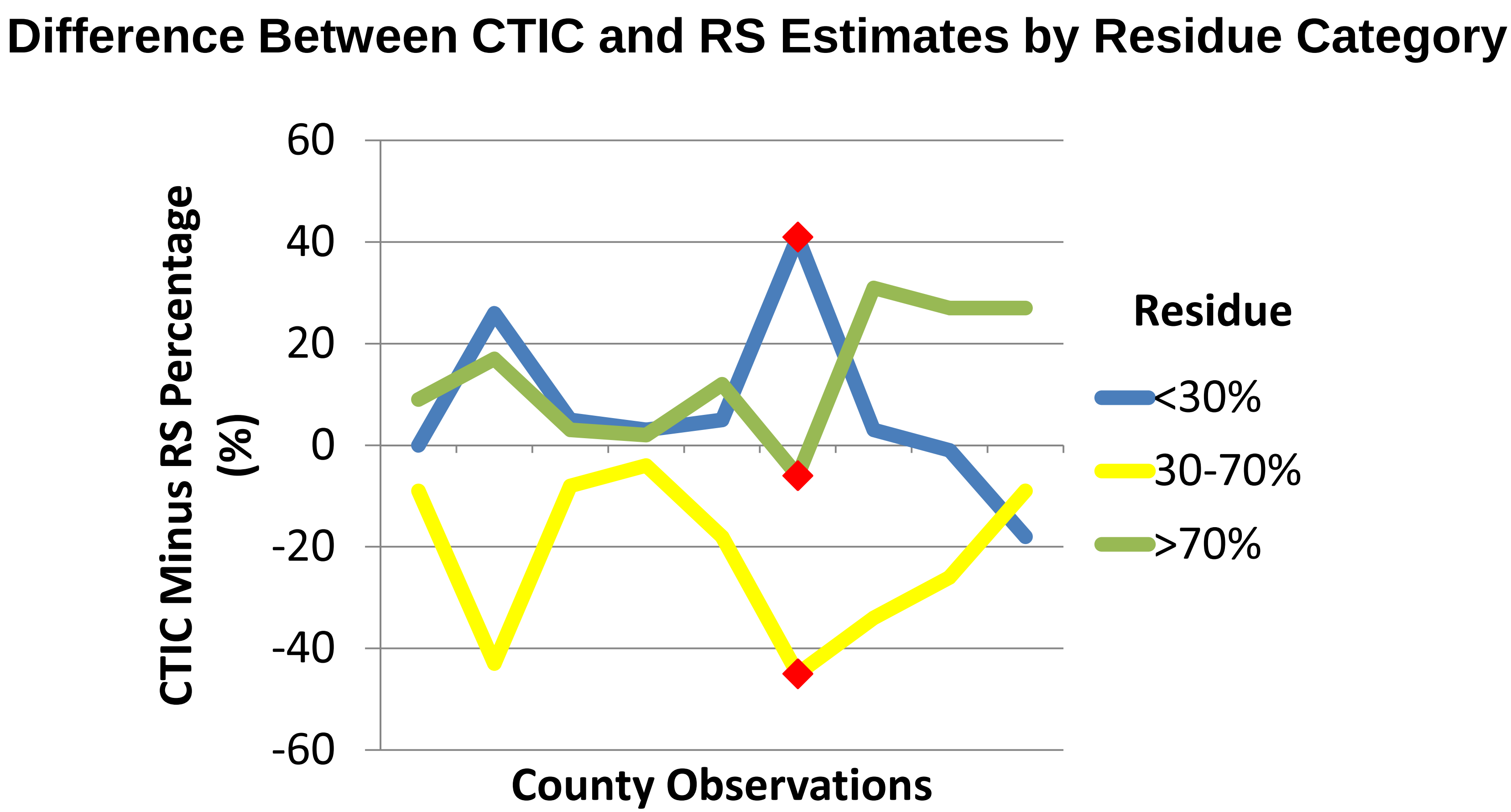
[1]The Corn + Bean data groupings were not the sum of Corn and Bean groups because additional fields that had both corn and soybean residue mixed in the same field were included in the Corn + Bean group.

Evaluated Hill method on 161 fields in Minnesota. Compared roadside vs. field estimates or residue cover. 0-15, 16-30, 31-50, 51-75, and 76-100%

Thoma et al. 2004

Cover Category Based on Field Measurement	n	% Visual Estimates from Roadside Transect Survey that were Below, Above, or Equal to the Measured Crop Residue		
		Below	Above	Equal
0-9.9%	55	0	27	73
10-19.9%	38	8	55	37
20-24.9%	18	39	56	5
25-34.9%	24	46	12	42
35-44.9%	12	25	0	75
45-54.9%	7	86	0	14
55-69.9%	6	50	0	50
70-100%	1	0	0	100

Zheng et al. 2013



Compared estimates from remote sensing with CTIC county data.

Observations from Literature

- Field verification of residue categories by actual measurement is important in determining error
- Oblique angles result in overestimation of crop residue when <25% cover
- Estimates generally less accurate from 10-35% residue cover (overestimate 0-25%, underestimate 20-70%)
- Fewer residue categories improves accuracy
- Error sources include changing personnel, inherent bias of observers, small representation of fields in the county

Roadside Transect Survey Method

- *Cropland Roadside Survey Method: Procedures for Cropland Transect Surveys for Obtaining Reliable County- and Watershed-Level Tillage, Crop Residue, and Soil Loss Data* (Hill 1998)
- "*when conducted properly*, this [method] provides a high degree of confidence in the data summaries"
- Used by CTIC, DE, and PA

Hill Method

- Establish route (cropland, ≥110 miles, crisscross county)
- Select survey dates
  - E.g., Residue after spring planting/emergence and before canopy closure
  - Cover crops early fall and late spring
- Survey team and training
- Determine data to be collected (k value)
- Determine sample size (multinomial)
- Field verification
- Calculations

Sample Size

- If two choices, use binomial assumption
- Otherwise, multinomial assumption
  - Tortora, R.D. 1978. A note on sample size estimation for multinomial populations. *The American Statistician* 32(3):100-102

Survey Team and Training

- Hill recommended county Extension agent, NRCS district conservationist, FSA county director, and a 4th person
- Four functions: Driver, route tracker, data recorder, field verifications
- PA uses 3 people in vehicle: county agriculture agency staffer, a highly trained consulting technician*, and a data entry technician* (*serve multiple counties). An independent QC technician performs QC on 10% of observation points
- Training: 1-day, photo guides, field examples, in-field post-training, PA addressing oblique angle issue

Data Collection

- Even-interval distances from starting point (e.g., 0.5 miles)
- Observations at each point on each side of road
  - No data collected if no cropland field
- Typically 10 percent of crop observations are checked by QC technician
  - Use this data to determine accuracy!

Calculations

Total acreage of crop A: $Acreage_A$
Total number of sample points in crop A: $Points_A$
Total number of crop A sample points in category I: $Points_{AI}$

$$Acreage_{AI} = Acreage_A \times \frac{Points_{AI}}{Points_A}$$

For example, if there are 80,000 acres of soybeans, 200 observation points with soybeans as the crop, and 50 soybean observation points with <30% residue, the total acreage of soybeans with <30% residue is calculated as:

$$Acreage = 80{,}000\ x\ \frac{50}{200} = 20{,}000\ acres$$

Tortora (1978)

$$n = \chi^2_{\left(1,1-\left(\frac{a}{k}\right)\right)} \times q(1-q)/d^2$$

n = sample size

$X^2_{\left(1,1-\left(\frac{a}{k}\right)\right)}$ **= Chi-square value for one d.f. and the value (1-(a/k)) substituted for (1-α)**

a = 1-p

p = confidence level we want in the proportions arrived at for each category

k = number of categories

q = a priori estimate of the proportion for each category (as a decimal). Use the q value for the category closest to 0.50 to ensure that sample size is sufficient for all categories. Use 0.50 when unknown

d = allowable error in the proportions (e.g., +/- 10%), expressed as a decimal

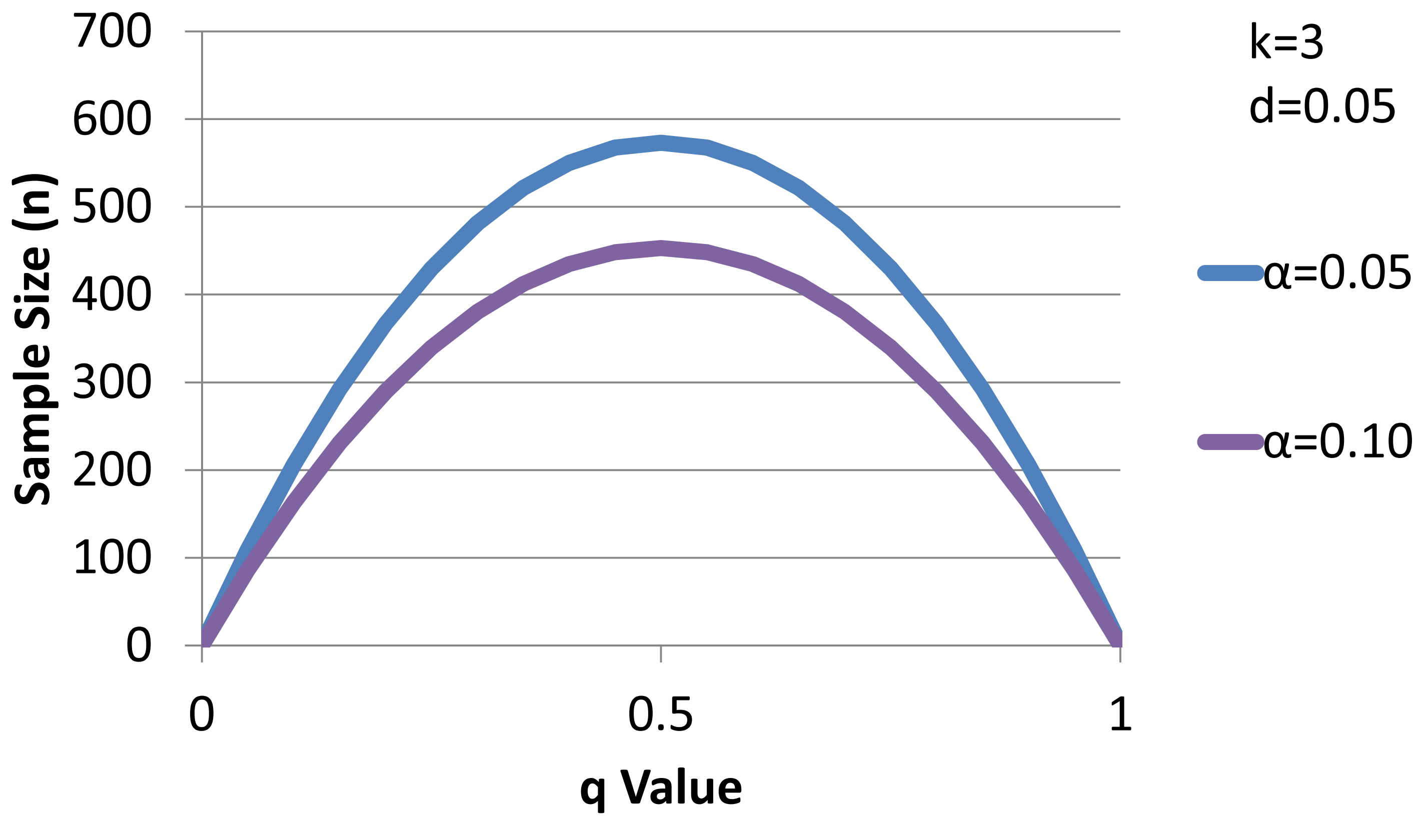
k Values: Residue Survey

- Phase 6 Model: k=4 (or greater)
  - Conventional/high tillage (<15% residue cover OR 15-29% residue cover with full width tillage)
  - Low residue, strip till/no-till (15-29% residue cover, strip till or no till, and less than 40% soil disturbance)
  - Conservation tillage (30-59% residue cover)
  - High residue, minimum soil disturbance tillage (≥60% cover, minimum disturbance)

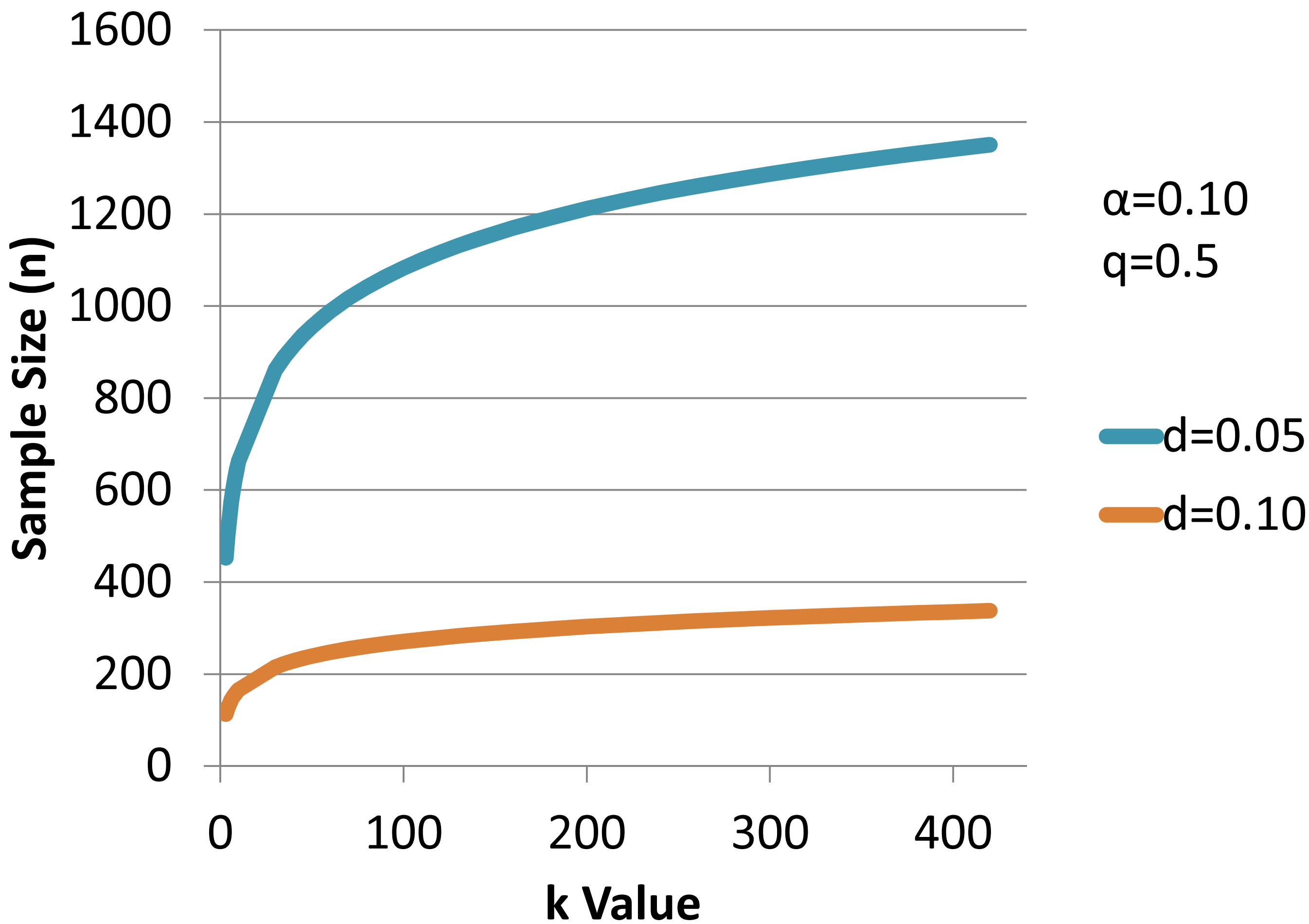
k Values: Cover Crops

- Phase 6 Model: k up to 420
  - 3 types (traditional, traditional w/fall nutrients, commodity), 14 species, 3 planting dates (early, normal, late), 3 planting methods (aerial, drilled, other)
  - 3 X 14 X 3 X 3 = 378
    - BUT only 104 of the combinations are possible in practice
  - Add “No Cover Crop” for calculations of acreages of various cover crops, so now 105 combinations
    - BUT, unique efficiency values for common low-till land uses and common high-till land uses in Coastal Plain/Piedmont crystalline/karst and Mesozoic lowlands/valley and ridge siliciclastic (2 X 2 = 4)
  - 4 X 105 = 420

Sample Size as a Function of Confidence Level (1-α) and Proportion (q)



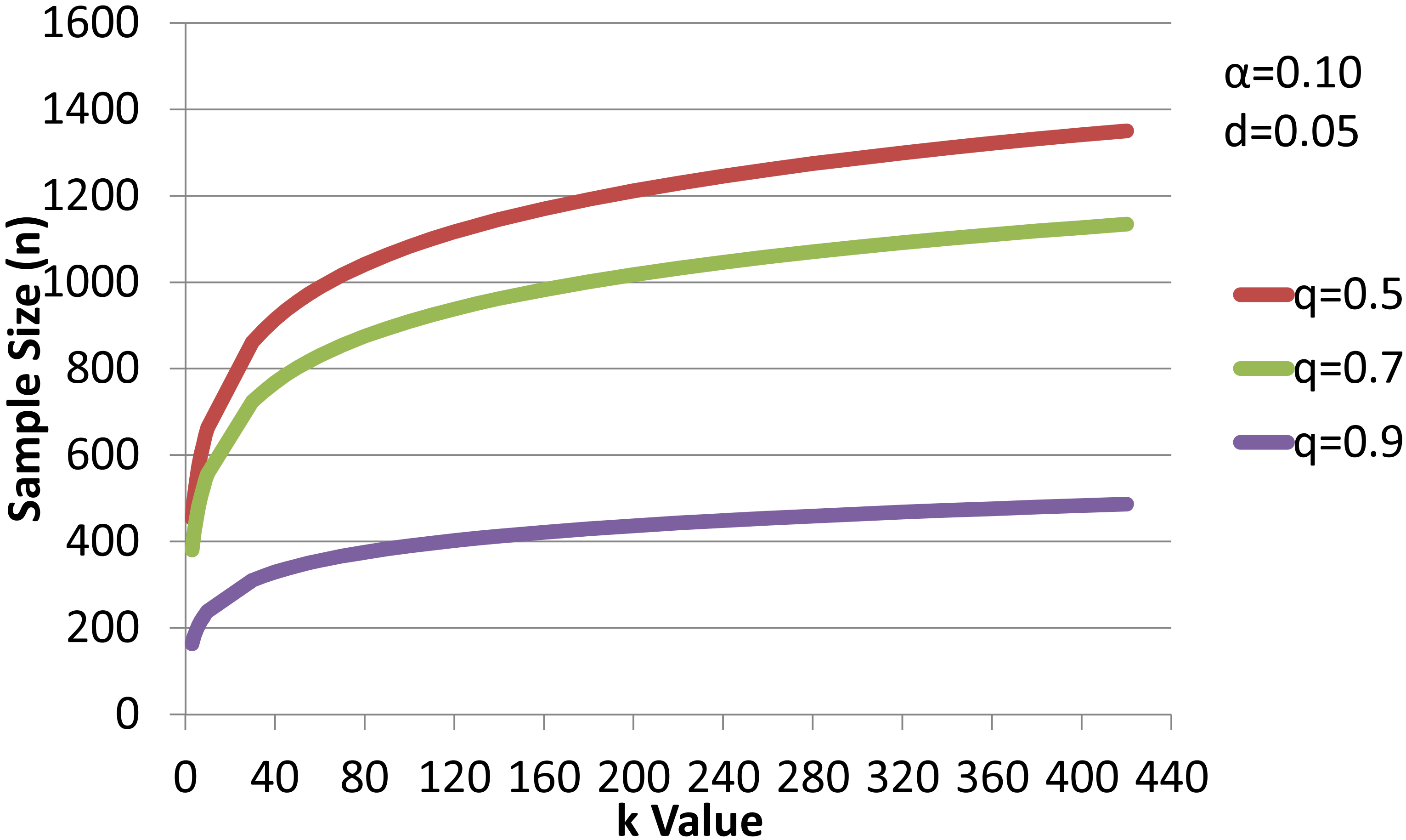
Sample Size as a Function of Number of Categories (k) and Error Margin (d)



Considerations

- Consider tracking narrower set of categories of residue or cover crop based on:
  - Predominant practice or species
  - N, P, and TSS efficiencies (focus on maximizing credit for lowest cost)
  - Groupings to accomplish above
- Alternatively, if q values are 0.15 or lower for all categories, sample size may not increase too much with greater k value
  - Should estimate q=0.5 if have no data. Over time will have better estimates
- Consider increased sample size if urbanization is an issue
  - Perhaps by 2.5% over 10 years; 5% over 20 years
- Increase sample size if expect substantial number of "no cropland" observations

Sample Size as a Function of k and q



Sample Count Error Matrix

Class		Reference/Ground Truth				Row Total	Marginal Proportions
		1	2	3	4		
Roadside Transect Results	1	$n_{1,1}$	$n_{1,2}$	$n_{1,3}$	$n_{1,4}$	$\boldsymbol{n_{1+}}$	w_1
	2	$n_{2,1}$	$n_{2,2}$	$n_{2,3}$	$n_{2,4}$	$\boldsymbol{n_{2+}}$	w_2
	3	$n_{3,1}$	$n_{3,2}$	$n_{3,3}$	$n_{3,4}$	$\boldsymbol{n_{3+}}$	w_3
	4	$n_{4,1}$	$n_{4,2}$	$n_{4,3}$	$n_{4,4}$	$\boldsymbol{n_{4+}}$	w_4
Column Total		$\boldsymbol{n_{+1}}$	$\boldsymbol{n_{+2}}$	$\boldsymbol{n_{+3}}$	$\boldsymbol{n_{+4}}$	$\boldsymbol{n}$	

Assumes 4 categories (k=4); e.g., <15%, ≥15<30%, ≥30<60%, and ≥60%

The marginal proportions, w_i, are the proportion of data classified into each category using all data from the roadside transect (and would not likely equal $\boldsymbol{n_{i+}}/\boldsymbol{n}$)

Calculation of True Proportions and Confidence Limits

- Procedures by Congalton and Green (2008) and Olofsson et al. (2013)
- Unbiased estimators of individual cell probabilities can be calculated by adjusting for the marginal proportions using the below equation

$$\hat{p}_{i,j} = w_i \left(\frac{n_{i,j}}{n_{i+}} \right)$$

Example

Sample Count Error Matrix			Reference/Ground Truth				Row Total	Marginal Proportions
	Class		1	2	3	4		
	Classified Data	1	20	10	4	1	35	0.3
		2	3	25	5	2	35	0.4
		3	1	3	20	6	30	0.1
		4	1	2	3	15	21	0.2
	Column Total		25	40	32	24	121	

- 20 roadside transect observations classified as Category 1 and confirmed as Category 1
- 4 roadside transect observations classified as Category 1 but found to be in Category 3 during ground truthing

- Unbiased estimators of the individual cell probabilities can be calculated using the equation in the previous slide and the values here
  - E.g., 0.3(4/35) = 0.034

Example

Area Proportion Error Matrix			Reference/Ground Truth				Row Total	
			1	2	3	4		
	Classified Data	1	0.171	0.086	0.034	0.009	0.3	
		2	0.034	0.286	0.057	0.023	0.4	
		3	0.003	0.010	0.067	0.020	0.1	
		4	0.010	0.019	0.029	0.143	0.2	
	Column Total (true proportions w/ 90% CI)		0.219 ±0.055	0.400 ±0.068	0.187 ±0.056	0.194 ±0.046		
	Producer's Accuracy		0.784	0.713	0.357	0.735		
	User's Accuracy		0.571	0.714	0.667	0.714		
	Overall Accuracy						0.667	

Summing the columns yields the unbiased estimators of the true marginal proportions ($\hat{p}_{+j}$)

Thus, while the roadside transect survey results indicated 30% of the total area in in Category 1 (i.e., w_1=0.3), only 21.9% ±5.5% of the total area is expected to be in Category 1 after accounting for bias computed based on a comparison to ground-truth data

Example

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Overall Accuracy						0.667

Equations (see document) are also available to calculate the variance of $\hat{p}_{+j}$ values using the data from the table. The variance is then used to calculate the Producer's Accuracy (the fraction of observations in a class correctly assigned to the class) and User's Accuracy (the fraction of observations assigned to a classification correctly)

The Overall Accuracy is the sum of the individual cell probabilities along the diagonal: 0.171 + 0.286 + 0.067 + 0.143 = 0.667. Variance can also be calculated: in this case 66.7% ±7%

Recommendations

- Two-step process may be appropriate where the first step requires that the following conditions be met:
  - Methodology is in conformance with the Hill methodology or a documented alternative
  - Route, survey dates, survey team qualifications, training, data collection
  - Use most accurate data available on crop acreages
  - Calculate sample size using multinomial equation and best estimates of q values and anticipated loss of cropland over time

Recommendations (cont.)

- Sample size
  - Minimum confidence interval of 90 percent
  - Allowable error (d) not to exceed 0.10
  - *A priori* value of q = 0.5 unless information is available to justify an alternative value
  - Add 5 percent to sample size to allow for site loss due to urban encroachment unless an alternative value can be justified
  - Inflate sample size proportionately to account for anticipated “non-cropland” observations
  - If combine residue survey and cover crop survey using same route and sample points, calculate “n” for both and use the greater value. Randomly select subset of sample points for the lesser “n” value
- Include field verification for determination of accuracy (10% has been used)

Recommendations (cont.)

- Second Step
  - Include a quality assurance analysis with the following:
    - Report the sample count error matrix
    - Report the area proportion matrix (including confidence intervals of the true proportions)
    - Report producer’s, user’s, and overall accuracy estimates, including the confidence interval of the overall accuracy estimate
    - Lower confidence limit on the overall accuracy >50 percent required for use of the true proportions resulting from the analysis
    - Minimum confidence level of 90 percent for all statistics

Discussion