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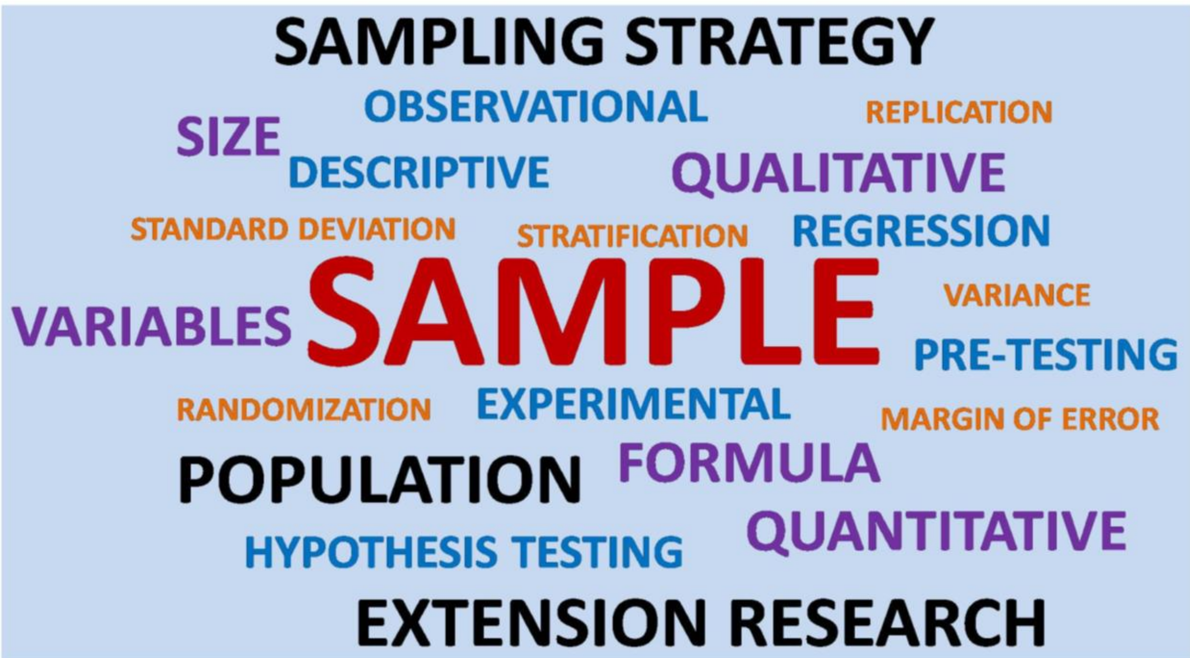
Agricultural Extension in South Asia

SAMPLE SIZE FOR EXTENSION RESEARCH – PART 1. QUANTITATIVE STUDIES

Non-availability of sound guidelines for sample size estimation is the primary factor affecting the quality of extension research in the country. In this blog, Dr P Sethuraman Sivakumar presents guidelines for choosing adequate sample for extension research.

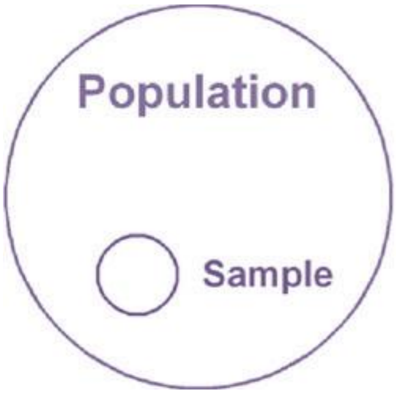
CONTEXT

Sample size is of primary importance for any applied scientific research as it directly influences the validity and generalisability of the research findings. . In extension science, empirical research is expected to yield sound extension tools and techniques to help the field functionaries effectively implement extension programmes. However, the empirical extension research is often conducted with smaller samples, which is confined to a specific geographical or demographical population (Sivakumar and Sulaiman, 2015). Social science studies conducted with inadequate sample sizes are vulnerable to inconsistencies. Such studies are likely to produce contradictory findings when conducted on the same research problem on an identical population (Johnson and Lauren, 2013). Though there are many factors responsible for the small sample extension research, the non-availability of sound guidelines for sample size estimation is the primary factor affecting the quality of extension research in the country. The purpose of this blog is to describe the sample size estimation process and provide guidelines for choosing adequate sample for both the quantitative and qualitative studies in extension research.



SAMPLING STRATEGY

The strategy is the plan devised by the researcher to ensure sample chosen for the research work represents the selected population. Choosing an appropriate sampling strategy is a key aspect of the research design. Robinson (2014) proposed a four-point sampling process for systematically selecting adequate samples for obtaining quality results.



1. Define a sample universe: Establish a sample universe, specifically by way of a set of inclusion and/or exclusion criteria. Inclusion criteria specifies the attribute(s) that respondents must possess to qualify for the study and the exclusion criteria stipulate attributes that disqualify a case from the study. For example, in a research investigation focusing on the "Information source utilisation of Ber growers", the inclusion criteria is "Ber grower (Current/ past specified in years)", while the exclusion criteria is "growers of other crops". During the selection, the homogeneity of the samples i.e., demographic (e.g. youth), geographical (e.g. Maharashtra or Tamil Nadu), physical (e.g. female workers), psychological (progressive farmers) and life history (e.g., migrant workers) should be considered.

2. Deciding on sample size: The size of a sample used for a quantitative or qualitative extension research is influenced by both the theoretical and practical considerations. The theoretical considerations for quantitative studies include the nature of problem, the population size and the type of analytical strategies used; while qualitative investigations focus on the saturation and redundancy of the data collection methods (Robinson, 2014). The practical aspects include the time and resource availability, researcher capability and purpose of research work (e.g., for dissertations or sponsored research).

3. Selecting a Sample Strategy: The popular sampling methods in quantitative research are probabilistic and non-probabilistic sampling, while qualitative research uses random/convenience sampling and purposive sampling strategies. After deciding on the sampling strategy, the respondents required for each sample category (e.g., strata) is decided from the overall sample size.

4. Sourcing sample: When the sample universe, size and strategy are decided, the researcher needs to recruit the participants from the real world. Voluntary participation, recruiting students from the subject pools, advertising in social and print media for recruiting community members, online surveys with jackpot provisions are few ways of recruiting participants for research work. In this phase, the researcher should follow ethical guidelines (if suggested by the ethics committee) in advertising, selection and handling participants, confidentiality of research data, compensating participants for their time and effort, etc. However, the extension research in India is conducted without following any ethical practices as suggested by various "Human Subject Research" regulatory agencies. The ignorance and non-compliance with International ethical guidelines poses serious problems when the research outcomes are published in peer-reviewed international journals.

SAMPLE SIZE ESTIMATION FOR QUANTITATIVE EXTENSION RESEARCH

In the quantitative extension research, the samples are drawn through either probabilistic or non-probabilistic sampling techniques and stratified random sampling is widely used by the researchers. Though the sampling methods specify few guidelines on the number of samples to be selected, the sample size is dependent on various other factors like type of study, nature and size of the population and choice of statistical analytical methods for the study. Other factors which help in deciding the sample size include the following:

- confidence level at which the results are interpreted,
- acceptable levels of sampling errors and precision of the results expected,
- effect sizes required,
- variance and standard deviations of the primary variables reported by the past work.

In case of self-report methods, the expected response rates also influence the sample size since poor response rates are likely to reduce the sample numbers required and affect validity of the research.

The following are the factors to be considered while selecting the sample size for a quantitative study:

(1) Type of research investigation and test population: The type of research investigation whether descriptive and observational or experimental, determines the number of samples required for the work. The descriptive studies employ minimal statistical estimation procedures like proportions and Chi-square tests, and sample size estimation procedures are described in the following sections. For experimental studies involving human subjects (e.g., knowledge gain from a multimedia instruction), the sample size depends on the design – replication, randomisation and stratification. The test population size also plays a crucial role in sample size estimation and the quantitative methods often require samples representing a maximum of 5% of the total population (Henry, 1990). The study population size can also be derived from past studies and secondary data sources (e.g. agricultural census). If the population size is unknown, the sample size can be estimated using the modified procedures as described in Box 1.

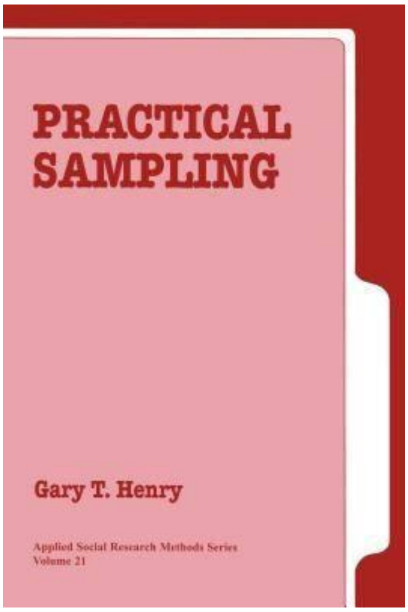


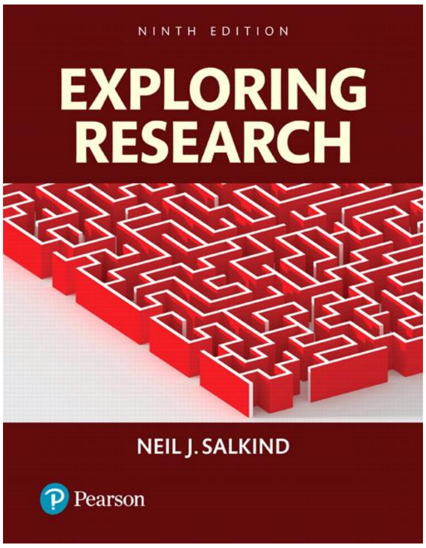
Table 1. Necessary Sample Size to Detect a Given Effect Size for Simple Linear Regression, ANOVA (t-test), and χ^2 Analyses (α = 0.05 and β = 0.20).			
Multiple regression		ANOVA and t test	
Correlation coefficient (*r*)	Reqd. Sample size (N)	Eta (η)	Reqd. Sample size (N)
0.10	782	0.10	396
0.15	346	0.15	176
0.20	193	0.20	99
0.25	123	0.25	64
0.30	84	0.30	44
0.35	61	0.35	33
0.40	46	0.40	25
0.45	36	0.45	20
0.50	29	0.50	16
0.55	23	0.55	14
0.60	19	0.60	11
0.65	16	0.65	10
0.70	13	0.70	9
0.75	11	0.75	8
(Source: Gatsonis and Sampson, 1989)			

(2) Primary variable(s) of measurement: A research investigation may use a variety of dependent and independent variables. For estimating the sample size, the researcher should decide the primary variables (dependent and few significant independent variables) to be included in the study. After deciding on the primary variables, the sample sizes are estimated separately for each primary variable or combinations using the formulae given in the Box 1. For example, if a researcher wishes to conduct a study on the factors influencing adoption of IPM for tomato crop, he/she should review the past studies to know the primary independent variables influenced adoption (e.g., gender, educational status, scientific orientation etc). Using the estimates of those variables (e.g., educational qualification correlation coefficient with adoption), the researcher can decide on the sample size using Table 1. After estimating the sample size for all primary independent variables individually, the researcher must choose the largest estimated sample size for the investigation.

(3) Acceptable Margin of Error – confidence intervals and confidence levels: The margin of error is the error the researcher is willing to accept in the study. The margin of error depends on the confidence interval, which is a measure of probability that a population parameter will fall between two set values. In any empirical research, we are selecting samples to estimate few numerical values for describing or analysing certain attributes of the respondents. The confidence intervals provide a range of values which represent a population parameter (e.g. adoption level of a crop variety or animal breed in the full population of the farmers in the real world) and tell us this that these values are true with a probability level (eg., 90%, 95% or 99%).

These probability levels are called as confidence levels. In any descriptive or analytical study, the confidence intervals are presented along with the mean and standard deviation of a specific attribute or variable. The confidence interval provides a range of values around the mean (both + or - mean) which represent the value of marginal error. It is necessary to decide on the allowable margin of error prior to the survey for calculating the appropriate sample size. It is decided by scanning through the past research studies on the same topic and identifying the reported mean values of primary variables. For example, if a researcher wishes to conduct a study on "Effectiveness of the training programme" with "Knowledge gain" as the primary variable, he/she should find the knowledge gain mean values reported from the past studies and decide on the value to be used for sample size estimation. In social research, a maximum of 5 percentage points around the mean is used as marginal error (Krejcie and Morgan, 1970).

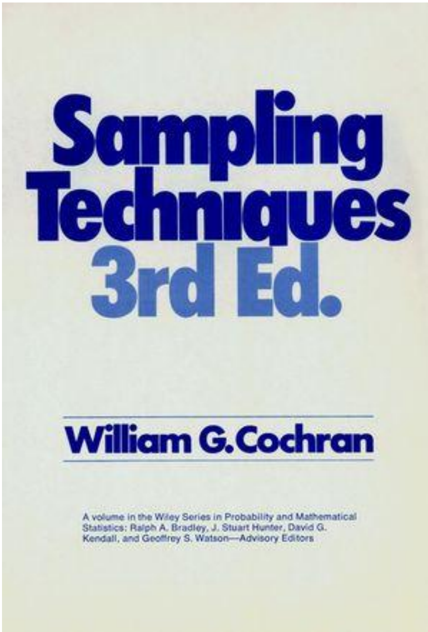
The confidence level indicates an alpha error value in hypothesis testing. The alpha (α) or type I error is a false-positive error of rejecting the null hypothesis that is actually true in the population, while the beta (β) or type II error indicates a false-negative error of failing to reject the false null hypothesis. Statistical power is probability of correctly rejecting the null hypothesis and is represented as $1 - \beta$. During sample size estimation, we are trying to reduce the alpha error by selecting a lower significance level of either 0.05 (95%) or 0.01 (99%) of the test. While an alpha level of 0.05 (5% probability for error) is acceptable for most social research, 0.01 (1% probability for error) is preferred when critical decisions are taken using the research results. As indicated in the previous paragraph, the confidence intervals are always expressed with a specific confidence levels (alpha error). The β error is not as serious as α error, but it is of particular concern when interpreting the results of a negative study, without statistical significance (no statistical significance or there is small significance and the test is unable to detect it). Statistical power for any sample estimation is conventionally set at 0.80 i.e. $\beta = 0.20$.



(4) Effect size: The effect size represents the size of the association between variables or difference between treatments the researcher expects to be present in the sample. If the researcher expects that his/her study to detect even a smaller association or difference between variables with precision, then he/she may need a larger sample size. For example, the knowledge gain from multimedia extension module can be detected precisely when the researcher tests the module with a large sample. In descriptive studies, the association or difference between the variables is reflected by the amplitude of the confidence interval calculated in the estimation. The effect sizes can be estimated from the reported values of association or effect from previous studies using Cohen's D, odds ratio, correlation coefficient and eta square methods. In general, the effect size (Cohen's d) of 0.2 to 0.3 is considered as "small", around 0.5 a "medium" effect and 0.8 to infinity, a "large" effect (Cohen, 1988). As a thumb rule, the associations or differences between variables reported in the past studies with "small" effect, require a large sample size for further studies.

Various online effect size calculators are available in the Psychometrica website (http://www.psychometrica.de/effect_size.html).

(5) Variance or Standard Deviation: When the variables analysed in the study are of a quantitative nature, their variability (variance or standard deviation) is considered for sample size estimation. Variance is a measurement of the spread between numbers or observations in a data set and is a square of standard deviation. The variance measures how far each number or observation in the data set is from the mean.



Cochran (1977) listed ways of estimating population variances or standard deviations for sample size estimations: (1) Select the sample in two steps, i.e. select the first sample and estimate the variance through pilot study and use the estimated value for the selection of sample size estimation for the main study; (2) use data from previous studies of the same or a similar population; or (3) estimate or guess the structure of the population assisted by some logical mathematical results. If the researcher finds difficulty in obtaining variance values from the previous study, he/ she can use an arbitrary value of 50% (Krejcie and Morgan, 1970).

In case of descriptive studies involving proportions, the researcher must specify the response distribution (labelled as *p* in the sample size formula) i.e., the expected proportion of the population that have the attribute the researcher is estimating from the survey. This proportion can be obtained from past studies, a pilot study or through other secondary sources. For example, if a researcher wishes to assess the gender differences in effectiveness of training on vegetable cultivation, he/she should review past studies to know the gender difference values (e.g., percentage of females who are satisfied with training). If this proportion is unknown, it should be arbitrarily set to 50% for use in the equation 1a. In case of descriptive studies involving means, the response distribution is replaced by variance or standard deviation (s^2 in Equation 1b).

CALCULATION OF SAMPLE SIZE

The sample size estimation follows the various aspects discussed in the previous section. Considering the complexity of sample size estimation, a simple of way of deriving sample size based on the nature of the research investigation (pre-testing phase, descriptive and analytical or hypothesis testing) and type of statistical tests planned for the study.

(1) Pre-Testing (of Research Instrument): The pre-testing of the research instruments is a key phase of any social research study. The main purpose of the pre-test is to verify that the target audience understands the questions and proposed response options are used as intended by the researcher, and the respondents are able to answer meaningfully (Perneger et al., 2015). Identification of problems in the instrument —e.g., unclear question, unfamiliar word, ambiguous syntax, missing time-frame, lack of an appropriate answer—

lead to a modification of the instrument. The sample size for the pre-test in extension research is often decided based on few flexible criteria, without following any rigorous procedures. Past studies indicated that a sample size of minimum 30 respondents to achieve a reasonable statistical power to detect problems in the instrument (Perneger et al., 2015).

(2) Descriptive studies: Descriptive studies are conducted to explore and describe a test population or their attributes in a systematic way. These studies are designed to estimate population parameters from sample which do not involve testing hypotheses. The data generated through these studies are described by presenting frequencies, proportions and means. The sample size estimation procedures for descriptive studies proposed by Rodríguez del Águilaa, and González-Ramírezba (2014) are described in Box 1.

Box 1: Sample size estimation procedure for descriptive studies

A. FOR FINITE POPULATIONS (KNOWN POPULATION SIZE)

Studies involving categorical variables

When the descriptive studies involve only categorical variables (e.g. age, educational qualification, employment etc), the researcher can estimate only proportions of particular attribute Eg. Studies aim for describing a system (e.g. crop or animal production systems, ITK documentation). The sample size for studies involving categorical variables can be computed by the following formula (Rodríguez del Águilaa, and González-Ramírezba, 2014).

$$n = \frac{t_\alpha{}^2 * p * q * N}{(N-1) * e^2 + t_\alpha{}^2 * p * q} \quad \text{Equation 1a}$$

Where n = Sample size to be estimated; t_α = value of the normal curve associated to the confidence level; p = expected percentage of population having a particular attribute; q = (p-1); e = accepted margin of error (usually between 5 and 10%) and expressed as percentage and N = Population size

Studies involving interval or continuous variables

For the descriptive studies involving interval or ratio variables (e.g. attitude, knowledge gain), the descriptive labels such as mean, mode, median and standard deviation can be computed. The sample size for such studies can be estimated using following formula:

$$n = \frac{t_\alpha{}^2 * s^2 * N}{(N-1) * e^2 + t_\alpha{}^2 * s^2} \quad \text{Equation 1b}$$

Where n = Sample size to be estimated; t_α = value of the normal curve associated to the confidence level; s^2 = variance of the variable for which we want to estimate the mean; e = accepted margin of error (usually between 5 and 10%) and expressed as percentage and N = Population size

Correction for estimates exceeding 5% of total population

In case of finite populations (where total population size is known e.g. Dairy farmers living in a district), If the calculated sample size exceeds 5% of the population size, Cochran's (1977) correction formula should be used to estimate the final sample size.

$$n1 = \frac{n_0}{(1 + \frac{n_0}{N})} \text{ --- Equation 2}$$

Where N = Population size; n_0 = required return sample size according to Cochran's formula given in equation 1a or 1b; n_1 = required sample size because sample > 5% of population

Correction for response rate - Surveys

The response rate is a crucial aspect in any research study involving surveys requiring voluntary participation of the respondents. Poor response rates often reduce the sample size and hamper the accuracy of the results. Salkind (1997) recommended oversampling i.e. increasing the sample size to the extent that will account for anticipated poor return rate. Oversampling can be achieved through four methods: (1) take the sample in two steps, and use the results of the first step to estimate how many additional responses may be expected from the second step; (2) use pilot study results; (3) use responses rates from previous studies of the same or a similar population; or (4) estimate the response rate through a systematic study. When the response rate is calculated by using any one of the above methods, the final sample size may be calculated using the following formula:

$$n_2 = \frac{n_1}{Anticipated\ return\ rate}$$

Where n_2 = sample size adjusted for response rate; n_1 = required sample estimated from equations 1a or 1b or 2.

B. FOR INFINITE POPULATIONS

In the case of infinite populations (population size unknown), the size of the population exerts no influence and the formulae referring for proportions and means are simplified.

Estimation of proportion (Categorical variable)

$$n = \frac{{t_\alpha}^2 * p * q}{e^2}$$

Estimation of a mean (Continuous variable)

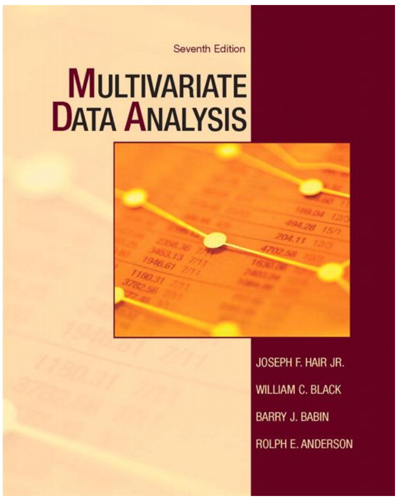
$$n = \frac{{t_\alpha}^2 * s^2}{e^2}$$

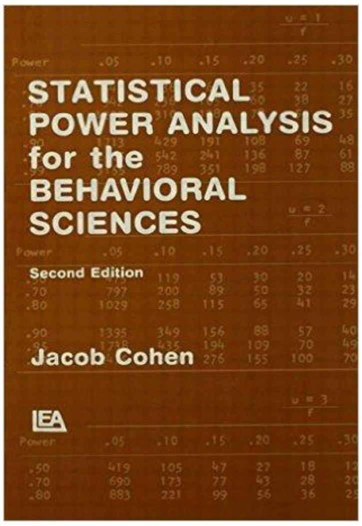
where n = sample size to be calculated; p = expected percentage of population having a particular attribute; q = 1 − p; s^2= variance of the variable for which we want to estimate the mean; e^2 = accepted margin of error; t_α = value of the normal curve associated to the confidence level.
After calculating the sample size, please estimate n_2 for correcting the response rate

3. Analytical studies involving hypothesis testing

Correlation and multiple regression

Regression analysis is used to examine the relationship between two interval- or ratio-scaled (continuous) variables. To estimate the minimum sample size for the multiple regression analysis, it is essential to understand the previously reported relationship / association between the dependent and independent variables. For example, if a researcher wishes to identify the factors which determine adoption of a biopesticide, he/she has to derive a value of association from the adoption level and independent variables like extension orientation, innovativeness, environmental consciousness etc from the previous studies. The association is represented by the "reported values of correlation coefficient (r)" between the adoption and independent variables. When the correlation coefficient is identified from previous studies, Table 1





(Gatsonis and Sampson, 1989) may be used to estimate required sample size (Weller, 2015). The table provides the sample size requirements for a given effect size (Correlation coefficient *r*) with default values of α = 0.05 and β = 0.20. The first column contains the minimum correlation that can be detected and the second column contains the minimum total sample size necessary to detect it.

In case of several independent variables used in a single study, the researcher may calculate sample sizes for all independent variables and choose the largest sample for the study. If the researcher is expecting a higher correlation between the dependent and independent variables from his/her study, the sample size can be selected based on the assumed value. The same procedure can be used for selecting sample sizes for the study involving estimation of Pearson correlation coefficient.

In case of research themes with no prior work or the correlation coefficients are not reported in the past studies, the method suggested by Maxwell (2000) may be followed. In this method, the correlations between the variables of interest are assumed as "medium", (r = 0.30 between dependent and independent variable) and the sample size is determined based on the number of independent variables for a default effect size of 0.80. Table no. 2 provides the required sample sizes derived using Maxwell's method (Maxwell, 2000).

Table 2. Necessary sample sizes based on the number of independent variables for multiple regression (r = 0.30; Power = 0.80)

Number of independent variables	**Required sample size**
2	141
3	218
4	311
5	419
6	543
7	682
8	838
9	1009
10	1196

(Source: Maxwell, 2000)

Logistic regression is a limited-dependent variable model and the sample size estimation procedures are described in Box 2.

Box 2: Sample size estimation for logistic regression

The sample size estimation for logistic regression is a complex process and four different approaches are proposed for the calculating adequate sample.

1. Method of confidence intervals - A univariate method which is suitable when the estimates are derived for a single variable.

2. Method of sample size evaluation in logistic regression – A simple and easy to use univariate method, which computes power, sample size, or minimum detectable odds ratio (OR) for logistic regression with a single binary covariate or two covariates and their interaction. The algorithm for this computation was developed by Demidenko (2007) and a sample size calculator is available at http://www.dartmouth.edu/~eugened/power-samplesize.php. Though this method was developed for medical studies, the calculator can also be used for extension research as the logic of variable selection and interpretation are similar in both cases.

3. Cross-validation – The cross-validation approach estimates the sample size by observing potential overfitting (Motrenko et al., 2014). Though this method is not associated with any model, it is complex and difficult to use by the amateur researchers.
4. Kullback–Leibler divergence method - This method compares different subsets of the same sample by using the Kullback–Leibler divergence (Perez-Cruz, 2008) between probability density functions of the model parameters, evaluated at similar subsets. It allows us to estimate the sample size for the multi-attribute sample set.

ANOVA and t test

An ANOVA (Analysis of Variance) test compares a single categorical independent variable (nominal, binary or ordinal) with more than two interval-scaled dependent variables. This is also called a one-way ANOVA, indicating only one independent variable. A special case of a one-way ANOVA occurs when the independent variable has only two categories. This comparison is often called a t-test, because the hypothesis test for difference between the two means uses the *t* probability distribution (Weller, 2015). The extension studies involving testing of effectiveness of multimedia on knowledge gain with same test group (pre-post test with paired "t" test) and analysing differences in the socio-economic and psychological attributes of adaptors, partial adopters and non-adopters (ANOVA) are examples of these analyses.

In *t* test and ANOVA analyses, the nominal to interval variable associations are analysed and the association or effect size can be calculated through eta (η) coefficient. The range of η is from 0 to 1, with a larger value indicating a stronger association (Weller, 2015). Columns 3 and 4 in Table 1 indicate the eta values and corresponding sample size requirement for ANOVA and t tests (Hays, 1963). Note that these estimates assume equal group sizes. The sample size estimation procedures for t test and ANOVA using online calculators is described in Box 3.

Box 3: Sample size estimation for "t" test and ANOVA using on-line calculators

In general, the extension studies involving t test and ANOVA published in the peer-reviewed journals rarely report the eta squared values, making it difficult for the aspiring researchers to decide on sample size for future studies. However, Table 1 provides the sample size estimates for corresponding eta values. This problem can be solved by calculating eta squared values using the effect size calculators(http://www.psychometrica.de/effect_size.html). The eta squared values can be converted to eta values for estimating sample size. To estimate the eta value, the following procedure may be adopted.

In case of t test, collect the *t* value along with sample size of each group (in case of independent t test where sample sizes of both groups are different) along with correlation coefficient between the selected variables (in case of dependent t test – paired t test). And then calculate d and r from the test statistics of dependent and independent t-testsby using the calculator no. 4 on the Psychometrica website. Repeat the procedure for all possible independent variables. When the d values are obtained, use the calculator no. 11 and **apply transformation of the effect sizes *d*, *r*, *f*, *Odds Ratio* and η^2.** This way eta square value for each independent variable can be estimated and converted it as eta by taking square root of each value. The required sample sizes can be chosen from Table 1 and select the largest sample size for the study.

In case of ANOVA, collect the F value, sample size of treatment and control groups from past studies and use calculator no. 5 to compute d from the F-value of Analyses of Variance (ANOVA). Repeat the procedure for all possible independent variables. When the d values are obtained, use calculator no. 11 to apply transformation of the effect sizes d, r, f, Odds Ratio and η^2 to estimate eta square value for each independent variable and convert it as eta by taking square root of each value. The required sample sizes can be chosen from Table 1 and select the largest sample size for the study.

Factor Analysis

The Exploratory factor analysis (EFA) and Principal Component Analysis are two commonly used factor analytical methods for scale construction in extension research. This multivariate technique should be used with the large sample size (over 100) for obtaining reliable estimates (Kline, 1994). In data reduction studies like attitude scale development, the researcher should follow the minimum respondent to variable ratio of 20:1 (i.e. 20 respondents per item selected for scale construction) (Hair et al., 2010). Selecting a large sample conforming to recommended respondent to item ratio, will increase the factor commonality besides decreasing the item loading value for selecting significant loadings in a particular factor (Hair et al., 2010). Table 3 provides the criteria for identifying significant item loadings on factors based on the sample size chosen for the study.

Table 3. Criteria for choosing significant item loading on each factor

Sample size	Minimum value of item loading in a factor/ component in the rotated component matrix (Significance value)
350	0.30
250	0.40
200	0.45
120	0.50
100	0.55
85	0.60
70	0.65

(Source: Hair et al., 2010).

CONCLUSION

Selecting adequate and representative sample is a key component of extension research. This paper has elaborated the sample size estimation process for quantitative extension research. Though sample size depends on the nature of research problem and population, the choice of statistical analytical procedures plays a crucial role in selecting the samples. The sample size estimation methods described in this paper are compiled from various published sources and the extension scientists can use them effectively for conducting quality research. The decision on sample size for the extension study depends largely on the past works. Most sample size formulae described in this blog demand the coefficients reported from past studies. However, the extension studies published in India haven't reported many coefficients that are essential for estimating sample size for future studies. A good publishing practice involves describing, analysing and reporting the science in a proper way which helps in advancing the knowledge besides guiding the future researches.

Online sample size calculators

A downloadable Excel file containing the macros to estimate sample size for descriptive studies (both categorical and continuous variables) developed by the author is available at https://drive.google.com/file/d/0BzwtVQNW-WqfYTYzSkVmZ3FDekk/view?usp=sharing

Other portals that offer "Ready-to-use calculators" to estimate the sample size for extension studies are as follows:

- National Statistical Service, Australia - http://www.nss.gov.au/nss/home.nsf/pages/Sample+size+calculator
- Raosoft Inc. - http://www.raosoft.com/samplesize.html?nosurvey
- Epi Tools - Sample size calculations - http://epitools.ausvet.com.au/content.php?page=SampleSize
- Psychometrica - http://www.psychometrica.de/effect_size.html

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