Data Analysis and Simulation for Stratified Random Sampling

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1 Functions and packages for Analyzing Data

```
library(latex2exp)
library(sampling)
library(plyr)
## this function finds statistical estimates given a dataset with sampling weight
# stratdata --- data.frame containing stratified sample
# y --- name of variable for which we want to estiamte population mean
# stratum --- name of variable that will be used as stratum variable
# weight --- name of variable indicating sampling weight
# post = TRUE is to indicate that we will do post-stratification analysis (ignoring it for the moment)
# note: from weights we can find Nh (see the code for formula)
str_mean_estimate_data <- function (stratdata, y, stratum, weight)
{
    ## compute stratum-wise data
    n <- nrow (stratdata)
    sh <- tapply (stratdata[, y], stratdata[,stratum], sd)
    ybarh <- tapply (stratdata[, y], stratdata[,stratum], mean)
    ## find population stratum size using sampling weight included in the data set
    Nh <- tapply (stratdata[, weight], stratdata[,stratum], sum)
    nh <- tapply (1:nrow(stratdata), stratdata[,stratum], length)
    ## find mean estimates
```

```r
    N <- sum (Nh)
    Pi_h <- Nh/N
    ybar <- sum(ybarh * Pi_h)
    seybar <- sqrt(sum((1-nh/Nh)*Pi_h^2*sh^2/nh))
    mem <- 1.96 * seybar
    c(Est. = ybar, S.E. = seybar, ci.low = ybar - mem, ci.upp = ybar + mem)

}


## to find total, multiply N to the estimate returned by this function
## for poststratification, use nh = n * Nh/N
str_mean_estimate <- function (ybarh, sh, nh, Nh)
{
    N <- sum (Nh)
    Pi_h <- Nh/N
    ybar <- sum(ybarh * Pi_h)
    seybar <- sqrt(sum((1-nh/Nh)*Pi_h^2*sh^2/nh))
    mem <- 1.96 * seybar
    c(Est. = ybar, S.E. = seybar, ci.low = ybar - mem, ci.upp = ybar + mem)
}



## sdata --- a vector of original survey data
## N --- population size
## to find total, multiply N to the estimate returned by this function

srs_mean_est <- function (sdata, N = Inf)
{
    n <- length (sdata)
    ybar <- mean (sdata)
    se.ybar <- sqrt((1 - n / N)) * sd (sdata) / sqrt(n)
    mem <- qt (0.975, df = n - 1) * se.ybar
    c (Est. = ybar, S.E. = se.ybar, ci.low = ybar - mem, ci.upp = ybar + mem)
}
```

2 Analysis of "agstrat.csv" data

2.1 Importing agstrat.csv data

```r
agstrat <- read.csv("data/agstrat.csv")
agstrat
```

```
##                        county state acres92 acres87 acres82 farms92 farms87
## 1             PIERCE COUNTY    NE  297326  332862  319619     725     857
## 2           JENNINGS COUNTY    IN  124694  131481  139111     658     671
## 3              WAYNE COUNTY    OH  246938  263457  268434    1582    1734
## 4          VAN BUREN COUNTY    MI  206781  190251  197055    1164    1278
## 5            OZAUKEE COUNTY    WI   78772   85201   89331     448     483
## 6         CLEARWATER COUNTY    MN  210897  229537  213105     583     699
## 7             POTTER COUNTY    SD  507101  552844  541015     321     371
## 8             HARDIN COUNTY    IA  332358  337990  355823     986    1065
```

```
## 9            VERNON COUNTY    MO  402202  396638  400466    1249    1251
## 10         SHERIDAN COUNTY    KS  535359  503582  513458     488     518
## 11         MACOUPIN COUNTY    IL  402310  444816  467453    1308    1509
## 12          CARROLL COUNTY    IL  238906  259634  270129     657     775
## 13          HOUSTON COUNTY    MN  272049  285056  286561     974    1073
## 14         CRAWFORD COUNTY    KS  302849  283589  325082     780     809
## 15      MISSISSIPPI COUNTY    MO  265245  259207  253150     293     340
## 16           PUTNAM COUNTY    IL   78081   85254   84630     201     242
## 17            STARK COUNTY    IL  169622  179267  179044     362     434
## 18             PIKE COUNTY    IN   85366   98958   96821     309     382
## 19          SHERMAN COUNTY    KS  620144  625942  672254     500     524
## 20        SHERBURNE COUNTY    MN  117701  124288  134960     530     604
## 21         MOULTRIE COUNTY    IL  184599  184566  183803     491     561
## 22      VANDERBURGH COUNTY    IN   80958   85852   81779     305     378
## 23             SAUK COUNTY    WI  335517  370141  388255    1383    1502
## 24            DODGE COUNTY    MN  241148  239443  269247     740     830
## 25          EDWARDS COUNTY    KS  403375  387309  382477     325     361
## 26           GREENE COUNTY    IL  303715  296591  312325     783     827
## 27            NANCE COUNTY    NE  236950  248639  245898     440     508
## 28             POLK COUNTY    IA  229818  238256  247261     832    1001
## 29           MONROE COUNTY    IA  223638  225145  222200     682     736
## 30            JONES COUNTY    SD  584231  594236  540344     198     213
## 31          WALLACE COUNTY    KS  471658  529749  505916     283     330
## 32        ALLAMAKEE COUNTY    IA  321728  321226  351756    1000    1062
## 33           THOMAS COUNTY    KS  702549  677199  658558     547     644
## 34         STODDARD COUNTY    MO  438142  434403  423972     953    1159
## 35            MIAMI COUNTY    IN  188843  196019  198468     771     818
## 36         CHEROKEE COUNTY    IA  336254  338708  340594     979    1091
## 37        HETTINGER COUNTY    ND  688468  724825  768099     427     525
## 38           RIPLEY COUNTY    IN  164025  173795  173605     963    1071
## 39            SCOTT COUNTY    MO  219042  241410  229535     545     642
## 40          CLINTON COUNTY    IL  229120  241466  246185     942    1115
## 41         MARSHALL COUNTY    IA  312858  330012  337775     949    1073
## 42         SULLIVAN COUNTY    IN  181020  188948  184890     544     599
## 43           MONONA COUNTY    IA  392835  377030  378621     822     854
## 44       JO DAVIESS COUNTY    IL  290454  313934  313436     955    1070
## 45         SEDGWICK COUNTY    KS  510319  523580  522674    1421    1589
## 46          HICKORY COUNTY    MO  174314  174007  155011     532     587
## 47         LAWRENCE COUNTY    SD  195077  207123  196321     272     253
## 48         LA SALLE COUNTY    IL  612112  641835  637108    1669    1978
## 49            DUNDY COUNTY    NE  528731  536373  557748     308     389
## 50           MASSAC COUNTY    IL   98838  103802  104233     401     414
## 51        ALEXANDER COUNTY    IL   69354   73076   78693     171     184
## 52       PENNINGTON COUNTY    MN  280089  305784  313450     480     585
## 53          SANILAC COUNTY    MI  444407  431199  444294    1433    1559
## 54         MONTCALM COUNTY    MI  224030  238387  240591     900     980
## 55         WALWORTH COUNTY    SD  448834  410375  421727     378     360
## 56            ALGER COUNTY    MI   16099   16140   17700      58      63
## 57             DOOR COUNTY    WI  130051  147860  155318     760     911
## 58           WARREN COUNTY    IA  302487  303783  320840    1216    1310
## 59             KNOX COUNTY    NE  612694  614959  641105    1086    1212
## 60            BARRY COUNTY    MI  165371  168493  188096     833     908
## 61          DOUGLAS COUNTY    IL  259498  271098  276455     682     807
## 62        JEFFERSON COUNTY    WI  232591  256282  269791    1280    1440
```

```
## 63         MINNEHAHA COUNTY    SD  425288  432472  425971    1262    1382
## 64              WOOD COUNTY    WI  221357  236904  242248    1029    1157
## 65           WAUPACA COUNTY    WI  241778  272429  274368    1190    1365
## 66            GRUNDY COUNTY    MO  226336  223823  245418     618     650
## 67            LOUISA COUNTY    IA  191291  198855  208670     554     634
## 68              GRAY COUNTY    KS  517623  532284  536969     497     547
## 69              HALL COUNTY    NE  316551  306869  304925     744     788
## 70             STONE COUNTY    MO  137747  148207  160233     698     782
## 71         BOLLINGER COUNTY    MO  197530  193547  210806     786     860
## 72            SHELBY COUNTY    IL  402212  422071  420047    1305    1431
## 73         FAIRFIELD COUNTY    OH  197736  214316  221802    1058    1217
## 74             DODGE COUNTY    NE  298854  321996  310513     855     962
## 75             TRIPP COUNTY    SD 1006831  960092  937667     741     770
## 76             WAYNE COUNTY    IN  189467  196898  200759     828     888
## 77         EFFINGHAM COUNTY    IL  257761  258305  255895    1140    1228
## 78          ATCHISON COUNTY    MO  304032  321878  306986     509     622
## 79            WASECA COUNTY    MN  237239  231788  247571     759     813
## 80           CALHOUN COUNTY    MI  244927  253383  266680    1080    1166
## 81         CODINGTON COUNTY    SD  392935  341159  352025     658     636
## 82          WATONWAN COUNTY    MN  249731  252824  260395     663     748
## 83           ELKHART COUNTY    IN  192311  204547  213225    1447    1556
## 84              ROCK COUNTY    WI  343115  357751  362206    1398    1518
## 85            NEMAHA COUNTY    NE  226042  241335  239728     511     591
## 86              LINN COUNTY    IA  349252  356000  368525    1529    1690
## 87            THAYER COUNTY    NE  347598  380147  362375     623     744
## 88            SALINE COUNTY    NE  312079  342898  331520     742     881
## 89          THURSTON COUNTY    NE  193556  193365  204344     386     462
## 90         HENDERSON COUNTY    IL  203974  212513  211574     468     522
## 91          DEARBORN COUNTY    IN   86236   90024   99239     738     796
## 92            EMMONS COUNTY    ND  834293  866121  813645     759     868
## 93          REPUBLIC COUNTY    KS  443290  440215  441118     746     833
## 94            ISANTI COUNTY    MN  131563  142998  153003     680     817
## 95            WARREN COUNTY    OH  129416  136623  154744     792     920
## 96             WORTH COUNTY    MO  134028  144572  155282     327     367
## 97       POTTAWATOMIE COUNTY    KS  451362  443660  464739     777     790
## 98            VINTON COUNTY    OH   41666   43303   50514     205     217
## 99             BROWN COUNTY    MN  347420  335559  339037    1190    1317
## 100             BOND COUNTY    IL  182572  186777  193237     629     714
## 101         CHEYENNE COUNTY    KS  592207  619870  602726     426     493
## 102             BOYD COUNTY    NE  296164  293720  282981     395     443
## 103             CASS COUNTY    NE  296016  338390  316564     721     913
## 104          CHESTER COUNTY    PA  176643  189943  219980    1367    1573
## 105           OSWEGO COUNTY    NY  112334  122648  139440     659     749
## 106          MONTOUR COUNTY    PA   41347   41870   48815     249     270
## 107       NEW LONDON COUNTY    CT   65987   74063   82709     550     556
## 108       CUMBERLAND COUNTY    ME   53893   57745   62096     440     456
## 109           FULTON COUNTY    PA   88982   99920  104793     438     467
## 110            ESSEX COUNTY    VT   17710   22237   26028      74      81
## 111         PLYMOUTH COUNTY    MA   72247   77140   80392     668     775
## 112           MONROE COUNTY    PA   20777   26898   29597     147     192
## 113          CLINTON COUNTY    NY  158392  172734  206396     488     591
## 114      ST LAWRENCE COUNTY    NY  396721  456497  493073    1367    1602
## 115           MORRIS COUNTY    NJ   23915   27086   25576     395     430
## 116       CUMBERLAND COUNTY    PA  141919  153746  163186     940    1100
```

```
## 117            YATES COUNTY    NY  102024  113922  112344     602     619
## 118         DELAWARE COUNTY    NY  192116  225899  297071     716     883
## 119         NEW YORK COUNTY    NY       0       0       0       0       0
## 120           ULSTER COUNTY    NY   69643   78437   85203     433     539
## 121            UNION COUNTY    PA   63159   64622   72935     451     505
## 122         SULLIVAN COUNTY    PA   30613   30496   35654     142     165
## 123       MONTGOMERY COUNTY    NY  138822  156368  164000     537     616
## 124           LEHIGH COUNTY    PA   82982   96931   95302     427     541
## 125         LAMPASAS COUNTY    TX  432379  404876  431276     689     615
## 126           MONROE COUNTY    GA   44599   39407   58630     179     160
## 127           LOVING COUNTY    TX  346653  415540  350350      14      17
## 128           FISHER COUNTY    TX  545666  504096  507523     547     629
## 129         SEMINOLE COUNTY    OK  250958  256310  256094     872     990
## 130          LINCOLN COUNTY    KY  173892  184377  181006    1444    1475
## 131           SEVIER COUNTY    AR  131353  126457  122126     549     558
## 132         GWINNETT COUNTY    GA   24239   29435   33762     345     441
## 133           FULTON COUNTY    GA   21975   32832   42527     235     344
## 134           SUMTER COUNTY    SC  138573  152452  177061     406     488
## 135          CHATHAM COUNTY    GA    8518   10641   12715      40      51
## 136       GREENBRIER COUNTY    WV  179736  191525  200127     705     729
## 137           TUCKER COUNTY    WV   32093   32123   36723     169     160
## 138          CARROLL COUNTY    MS  151743  173064  188333     394     431
## 139          QUITMAN COUNTY    MS  186297  199767  212667     219     256
## 140             HALE COUNTY    TX  560355  582208  610359     774     818
## 141         STERLING COUNTY    TX  835337  675977  726837      74      75
## 142       MONTGOMERY COUNTY    MD   82470  103377  106157     561     669
## 143       MONTGOMERY COUNTY    MS   80272   97454  110766     290     307
## 144           SABINE PARISH    LA   57789   58112   65071     414     468
## 145        CRAIGHEAD COUNTY    AR  350402  351106  345804     781     902
## 146            UNION COUNTY    NC  167379  170378  202639    1037    1086
## 147           CARTER COUNTY    OK  372901  402260  386472     992    1056
## 148          DECATUR COUNTY    GA  168593  163114  194568     342     376
## 149           CHOWAN COUNTY    NC   53902   50446   54749     179     220
## 150     HILLSBOROUGH COUNTY    FL  265443  287951  329293    2760    2754
## 151          CLAYTON COUNTY    GA    4519    8028    7137      56      73
## 152          LOWNDES COUNTY    AL  199714  207753  226744     315     378
## 153          LIBERTY COUNTY    GA   15583   18248   19965      49      41
## 154             RUSK COUNTY    TX  268058  271230  281569    1226    1327
## 155        TROUSDALE COUNTY    TN   55097   58550   58921     389     439
## 156       PERQUIMANS COUNTY    NC   68736   75808   86376     226     272
## 157        JEFFERSON COUNTY    WV   74268   83079   87648     334     363
## 158       OGLETHORPE COUNTY    GA   55310   63352   69948     303     314
## 159        GA RFIELD COUNTY    OK  662121  633271  659095    1152    1182
## 160             DALE COUNTY    AL  134555  129105  134743     403     490
## 161          CULLMAN COUNTY    AL  196859  193771  206050    2086    2210
## 162            DUVAL COUNTY    TX  801159  996776  970827     946    1151
## 163          SAMPSON COUNTY    NC  266067  263626  263007    1342    1477
## 164         CAMPBELL COUNTY    VA  134474  134093  143127     612     628
## 165           GREENE COUNTY    NC  112291  117207  107523     407     510
## 166           CARTER COUNTY    KY  112831  118340  118009     986    1025
## 167         GA TES COUNTY      NC   64532   68992   67985     199     251
## 168          ORLEANS PARISH    LA     100      11      13      17       7
## 169             HAYS COUNTY    TX  463450  297443  210668     704     701
## 170         EASTLAND COUNTY    TX  493227  433691  469113    1120    1085
```

```
## 171          TALBOT COUNTY    GA   38313   38854   41585     127     128
## 172       DODDRIDGE COUNTY    WV   59184   57795   59608     261     272
## 173         HICKMAN COUNTY    TN  130167  129661  130045     642     650
## 174           BURKE COUNTY    NC   31671   34833   35776     348     366
## 175         HOUSTON COUNTY    TX  417187  422172  450995    1360    1421
## 176            HALL COUNTY    TX  443027  393949  458988     297     296
## 177       MCCRACKEN COUNTY    KY   62766   70148   72377     404     434
## 178        MCCREARY COUNTY    KY   13887   11584   10946     114     116
## 179            HART COUNTY    KY  200455  194172  189316    1582    1518
## 180        SARASOTA COUNTY    FL  151242  166766  206976     328     352
## 181         PICKENS COUNTY    AL  106206  108861  133757     404     417
## 182            KING COUNTY    TX  436040  409706  418003      34      50
## 183          SALINE COUNTY    AR   45609   55253   58961     330     427
## 184         CALHOUN COUNTY    FL   43314   48166   55986     132     159
## 185        PRESIDIO COUNTY    TX 1695484 1890612 1981461     151     139
## 186           CLARK COUNTY    KY  144904  155437  147236     966     947
## 187          JASPER COUNTY    SC   72500  102205  103145     146     150
## 188       OCHILTREE COUNTY    TX  593819  607038  612836     374     391
## 189        CALLOWAY COUNTY    KY  137337  137781  152270     694     749
## 190       HABERSHAM COUNTY    GA   36074   39886   42024     455     452
## 191          COFFEE COUNTY    TN  132388  143496  152296     838     887
## 192          TAYLOR COUNTY    TX  509017  431408  435628     915     903
## 193         HAYWOOD COUNTY    NC   69961   79672   81070     812     912
## 194         BECKHAM COUNTY    OK  493631  495415  498195     732     815
## 195          COTTON COUNTY    OK  358446  347784  362443     540     513
## 196          DALLAS COUNTY    AR   20589   18918   25706     108     128
## 197          ORANGE COUNTY    VA  107700  113175  118613     419     424
## 198           SMITH COUNTY    TX  247626  249326  246909    1609    1701
## 199        ITAWAMBA COUNTY    MS   76673   78932   98384     417     452
## 200            NASH COUNTY    NC  179051  184304  214759     560     692
## 201      WASHINGTON COUNTY    TX  328367  338840  305119    1903    1983
## 202          WARREN COUNTY    KY  252817  239462  245457    1956    1866
## 203         DICKENS COUNTY    TX  561521  439124  513862     270     285
## 204          ORANGE COUNTY    NC   67491   81108   90575     433     522
## 205         HOPKINS COUNTY    KY  144828  144862  158726     617     620
## 206      ORANGEBURG COUNTY    SC  262093  292177  340090     910     961
## 207        HIGHLAND COUNTY    VA   96910   94880  103470     298     303
## 208          CITRUS COUNTY    FL   70672   74264   93183     288     331
## 209           WOLFE COUNTY    KY   61145   59856   67007     456     453
## 210      PASQUOTANK COUNTY    NC   83218   81626   73766     199     225
## 211         CATAWBA COUNTY    NC   62854   67408   81452     507     567
## 212      MONTGOMERY COUNTY    KY  113383  115897  121161     772     793
## 213          KIMBLE COUNTY    TX  774804  781013  720012     476     442
## 214          TWIGGS COUNTY    GA   31161   31693   40169     113     112
## 215        DAVIDSON COUNTY    TN   47319   57917   74003     440     561
## 216           SURRY COUNTY    VA   52770   46030   55565     110     126
## 217         WASHITA COUNTY    OK  577693  589015  586142    1004    1089
## 218          WETZEL COUNTY    WV   37130   36217   45877     199     203
## 219       OKTIBBEHA COUNTY    MS   80761   91819  124895     339     355
## 220         OVERTON COUNTY    TN  105519  110079  126718     818     842
## 221       SEBASTIAN COUNTY    AR  115019  118946  137686     689     738
## 222    CHESTERFIELD COUNTY    SC  109652  109613  139303     491     429
## 223            HOOD COUNTY    TX  225852  212741  238234     659     638
## 224            REAL COUNTY    TX  362642  318164  311411     215     189
```

```
## 225                LEE COUNTY    NC   37434   42636   52614     301     345
## 226             MONROE COUNTY    WV  148842  143762  153723     606     610
## 227         POCAHONTAS COUNTY    WV  115487  118540  129717     355     379
## 228          EDGECOMBE COUNTY    NC  180400  182498  219242     376     449
## 229             NOWATA COUNTY    OK  282659  231409  274430     695     679
## 230              WAYNE COUNTY    KY  135850  136970  140014     889     979
## 231          JEFFERSON COUNTY    TN   98669  109592  115196    1234    1326
## 232             JASPER COUNTY    TX   70165  101968   76097     532     602
## 233            CHOCTAW COUNTY    MS   42712   47224   76105     195     228
## 234             COFFEE COUNTY    GA  178861  178875  200598     711     649
## 235               POLK COUNTY    TX  141215  144390  161772     515     559
## 236           COLORADO COUNTY    TX  549167  559698  596786    1547    1589
## 237 WEST BATON ROUGE PARISH    LA   38566   42488   42970      90      95
## 238               KERR COUNTY    TX  531206  539371  589223     651     584
## 239         WASHINGTON COUNTY    AL   85086   86532   96955     361     416
## 240             GRAHAM COUNTY    NC    8882    7533   10507     147     147
## 241            CLINTON COUNTY    KY   75409   86085   87629     747     777
## 242           MCINTOSH COUNTY    GA    8003    5071    5107      33      23
## 243              TOWNS COUNTY    GA    9910   10638   13613     128     149
## 244            PULASKI COUNTY    GA   80396   86400   89515     137     163
## 245              LOGAN COUNTY    AR  186829  187992  187551     940     995
## 246       ANNE ARUNDEL COUNTY    MD   43320   42413   44722     477     567
## 247            WHEELER COUNTY    TX  501692  486321  492597     445     467
## 248             MONROE COUNTY    AR  219444  234605  235409     278     306
## 249           BEAUFORT COUNTY    NC  144529  156433  158281     447     630
## 250        NORTHAMPTON COUNTY    VA   52469   50530   62283     162     180
## 251             MENARD COUNTY    TX  487573  501761  463848     280     261
## 252           SAN SABA COUNTY    TX  743638  741678  708937     640     609
## 253          HENDERSON COUNTY    TX  356170  333190  323887    1579    1577
## 254             KENEDY COUNTY    TX  553226  621878  569640      29      24
## 255            CARROLL COUNTY    AR  246184  240838  252536    1031    1045
## 256             BRAZOS COUNTY    TX  295601  271421  256837    1006     971
## 257           COLUMBIA COUNTY    AR   57253   66305   80909     320     411
## 258            GREENUP COUNTY    KY  100468   93353   92487     849     824
## 259            FLEMING COUNTY    KY  193859  204660  177444    1232    1308
## 260             CUSTER COUNTY    ID  140701  137022  148063     267     261
## 261           UMATILLA COUNTY    OR 1466580 1451108 1407279    1441    1453
## 262          ESMERALDA COUNTY    NV 1949420 1798823 2133372      23      28
## 263               MAUI COUNTY    HI  355786  359310  403140     850     722
## 264            MILLARD COUNTY    UT  484156  480195  487961     612     630
## 265           DUCHESNE COUNTY    UT  399011  366471  315061     733     753
## 266             DAWSON COUNTY    MT 1334041 1326655 1353774     451     499
## 267            SHERMAN COUNTY    OR  487534  462424  431172     179     187
## 268               HILL COUNTY    MT 1644001 1722206 1734585     641     713
## 269             POWELL COUNTY    MT  675569  670508  742622     233     237
## 270           COLUMBIA COUNTY    OR   71839   73949   77182     661     695
## 271               EDDY COUNTY    NM 1138681  967816  957155     495     503
## 272            BENEWAH COUNTY    ID  111510  115100  124190     195     205
## 273          KLICKITAT COUNTY    WA  689639  698453  725048     508     545
## 274             HAWAII COUNTY    HI  926607 1007287 1172448    3157    2810
## 275              CROOK COUNTY    WY 1542262 1509320 1548500     442     461
## 276              TOOLE COUNTY    MT 1063086 1131519 1056130     358     393
## 277           GREENLEE COUNTY    AZ  137834  139840  141595     107     102
## 278              GRAND COUNTY    CO  299142  319578  284306     149     163
```

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## 279             UTAH COUNTY    UT  450315  493902  432326    1696    1723
## 280             POLK COUNTY    OR  167880  176178  179518    1027    1072
## 281        BEAR LAKE COUNTY    ID  269435  269211  292783     415     446
## 282       LAS ANIMAS COUNTY    CO 2286947 2149828 2137550     490     481
## 283          MADISON COUNTY    MT 1271160 1195898 1196626     418     453
## 284            EAGLE COUNTY    CO  213004  213441  201657     134     147
## 285            TETON COUNTY    ID  134788  148908  156160     257     268
## 286        ROOSEVELT COUNTY    MT 1414415 1364020 1371234     525     598
## 287           CARBON COUNTY    MT  598694  536553  628680     599     635
## 288           KITSAP COUNTY    WA   10302    9576   10974     366     404
## 289         HINSDALE COUNTY    CO    9021    9899   10920      16      16
## 290         HUMBOLDT COUNTY    CA  597766  616267  648820     874     890
## 291           SUMMIT COUNTY    UT  373582  348827  339347     419     439
## 292          STEVENS COUNTY    WA  546303  525783  578060    1054    1073
## 293            CLARK COUNTY    WA   82967   94646  101660    1257    1428
## 294        WAHKIAKUM COUNTY    WA   12611   14616   15915     110     135
## 295         FRANKLIN COUNTY    WA  670149  660813  632519     857     894
## 296              LEA COUNTY    NM 2149450 2220431 2178568     544     561
## 297         THURSTON COUNTY    WA   59890   56799   67628     811     806
## 298        CARSON CITY (IC)    NV    5361   17859   18780      28      37
## 299          BANNOCK COUNTY    ID  325338  358189  352306     588     655
## 300         LA PLATA COUNTY    CO  587339  613579  589167     709     682
##     farms82 largef92 largef87 largef82 smallf92 smallf87 smallf82 region   rn
## 1       865       54       54       42       58       67       48     NC  805
## 2       751       14       13       14       42       36       38     NC  241
## 3      1866       20       19       16      175      186      184     NC  913
## 4      1464       23       17        9       56       66       55     NC  478
## 5       527        6        5        5       56       49       48     NC 1028
## 6       693       34       32       23        8       19       13     NC  496
## 7       341      163      180      176       10       24       16     NC  969
## 8      1208       56       36       42       90      115      132     NC   42
## 9      1320       86       78       69       42       38       28     NC  676
## 10      571      216      204      193       16       37       24     NC  383
## 11     1754       80       77       56       71      108      117     NC  158
## 12      846       48       45       40       39       57       65     NC  107
## 13     1128       22       13       15       49       50       44     NC  509
## 14      915       73       61       65       34       40       44     NC  312
## 15      361      104       96       85       14       10        8     NC  635
## 16      261       12       16       16       12       12       18     NC  177
## 17      474       44       38       29       24       27       30     NC  187
## 18      413       12       14       11       14       24       13     NC  264
## 19      550      211      224      225       12       25       14     NC  384
## 20      684       20       19       14       20       22       18     NC  552
## 21      597       54       44       32       44       44       47     NC  169
## 22      408       15        9       11       26       40       41     NC  283
## 23     1635       30       24       19       60       54       58     NC 1039
## 24      933       47       43       49       44       63       76     NC  501
## 25      402      129      144      133       11       10       14     NC  317
## 26      912       71       66       58       56       62       55     NC  130
## 27      478       67       71       61       24       52       43     NC  798
## 28     1110       48       48       39       70      108      100     NC   77
## 29      761       31       25       24       26       34       28     NC   68
## 30      222      122      137      137       12       17        8     NC  953
## 31      338      142      161      148        6       30       27     NC  393
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## 32   1134   46   37   37   55   61   56   NC    3
## 33    628  236  248  221   12   20   18   NC  390
## 34   1338  132  109   94   21   45   62   NC  671
## 35    924   33   21   21   75   58   77   NC  253
## 36   1214   41   31   18   64   86   94   NC   18
## 37    502  275  301  295   14   14   14   NC  703
## 38   1165   18   15   15   55   55   67   NC  270
## 39    687   70   55   51   36   46   40   NC  668
## 40   1154   20   16   11   75   73   69   NC  113
## 41   1201   55   46   39   72   94  110   NC   64
## 42    660   52   48   36   49   43   29   NC  278
## 43    933  104   93   71   59   50   53   NC   67
## 44   1142   43   39   33   49   61   64   NC  142
## 45   1665  133  116  125  102  135  135   NC  380
## 46    562   25   32   22   13   20   13   NC  611
## 47    245   55   50   51   15   22   22   NC  956
## 48   2146   97   77   52   84  106  119   NC  149
## 49    382  150  171  178    7   26   17   NC  764
## 50    480   23   24   18   11   18    9   NC  163
## 51    246   20   16   19    2    2    9   NC  101
## 52    655   93   91   80   14   23   23   NC  538
## 53   1846   89   71   52   39   63   47   NC  474
## 54   1132   37   36   28   30   48   33   NC  457
## 55    405  158  163  176   26   22   21   NC  980
## 56     76    2    1    1    2    4    1   NC  400
## 57   1032    5    3    3   37   26   31   NC  997
## 58   1394   54   47   44   68   86   91   NC   91
## 59   1280  156  134  142   69   91   81   NC  789
## 60   1061   21   18   11   30   35   29   NC  406
## 61    845   74   59   47   69   74   56   NC  120
## 62   1602   20   15   16   79   84  101   NC 1010
## 63   1490   78   62   41   73   88   96   NC  965
## 64   1253   18   18   16   39   42   52   NC 1054
## 65   1488   12   17   13   53   69   67   NC 1051
## 66    740   54   52   51   19   30   35   NC  608
## 67    699   30   28   21   29   43   43   NC   58
## 68    552  181  183  170   20   37   23   NC  328
## 69    794   66   59   54   71   70   76   NC  775
## 70    824   16   15   13   21   41   35   NC  672
## 71    994   33   19   22   18   33   25   NC  577
## 72   1599   73   61   43   76   93   81   NC  186
## 73   1322   31   30   25   84   79   88   NC  851
## 74    977   61   53   38   88   98   75   NC  762
## 75    713  329  338  336   38   33   34   NC  977
## 76   1000   32   26   13   57   59   73   NC  290
## 77   1261   23   16   15   75   85   71   NC  124
## 78    669   88   80   61   22   36   19   NC  571
## 79    878   34   23   25   41   63   65   NC  562
## 80   1281   27   30   27   59   34   41   NC  411
## 81    675  121  100   95   33   27   47   NC  930
## 82    885   38   30   25   30   44   58   NC  564
## 83   1678   20   22   14  236  234  239   NC  221
## 84   1680   64   66   55  138  160  165   NC 1036
## 85    614   56   55   36   26   28   27   NC  799
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## 86    1810   44   35   27  134  135  128  NC   57
## 87     707  100  120   91   32   44   32  NC  820
## 88     905   63   58   38   56   47   39  NC  811
## 89     535   41   33   24   17   31   33  NC  822
## 90     562   48   41   36   35   22   26  NC  135
## 91     905    2    1    0   34   33   42  NC  216
## 92     849  352  355  328   15    6   24  NC  697
## 93     923  140  135  112   28   42   43  NC  372
## 94     947   18   14    8   14   26   34  NC  511
## 95    1048   24   22   20   61   73   76  NC  911
## 96     389   27   26   25   11   11   13  NC  681
## 97     869  129  124  122   26   50   48  NC  368
## 98     249    3    4    3   10    6    5  NC  910
## 99    1390   33   16   15   60   88   96  NC  489
## 100    824   28   35   30   32   50   35  NC  102
## 101    546  189  222  221   10   17   33  NC  305
## 102    442   99   91   93   28   39   35  NC  743
## 103    915   88   91   59   56   72   56  NC  748
## 104   1825   21   18   20  172  211  263  NE  149
## 105    826    3    4    4   40   35   32  NE  110
## 106    314    2    4    4    8   15   22  NE  181
## 107    573    1    1    2   66   55   52  NE    6
## 108    507    2    3    3   84   59   54  NE   28
## 109    491    5    5    7   10    9    8  NE  163
## 110     90    3    2    4    8    2    0  NE  211
## 111    649   12   10    6  153  158  121  NE   23
## 112    207    3    4    1   14   26   13  NE  179
## 113    705   14    9   14   19   25   23  NE   82
## 114   1807   41   30   20   37   46   35  NE  117
## 115    385    1    1    1  116  134  104  NE   65
## 116   1174    7    7    6   60   86   84  NE  155
## 117    617    3    9    8   18   29   32  NE  134
## 118   1067   15   14   21   28   56   40  NE   85
## 119      0    0    0    0    0    0    0  NE  103
## 120    570    9    6    8   54   84   57  NE  128
## 121    524    3    0    1   16   33   36  NE  194
## 122    187    3    1    1    7    9    3  NE  191
## 123    657    9    7    6   16   21   21  NE  101
## 124    574   15   16   11   66   74   61  NE  173
## 125    611  110  107  101   21   25   24   S 1116
## 126    172    5    7    9   12    9   11   S  311
## 127     15   13   12   10    0    1    1   S 1126
## 128    688  153  142  134   17   28   23   S 1051
## 129   1030   29   35   33   34   31   34   S  824
## 130   1611   11    7    8  185  181  236   S  437
## 131    567   11   12   16   28   30   23   S  134
## 132    492    1    1    1   51   60   44   S  276
## 133    379    3    5    6   40   58   61   S  269
## 134    567   40   45   45   45   54   56   S  877
## 135     59    4    4    5   10    8   15   S  234
## 136    790   29   33   31   31   23   23   S 1340
## 137    175    3    4    6    3    7    2   S 1374
## 138    490   32   34   33    8   12   11   S  583
## 139    323   57   66   73    6    7    6   S  635
```

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## 140     832      193      160      172       21       49       29        S 1070
## 141      78       54       54       58        4        5        2        S 1191
## 142     675       15       17       20       83       90       90        S  567
## 143     374       15       18       21       13       10       19        S  624
## 144     527        1        2        4       15       20       28        S  531
## 145    1020       94       78       75       24       36       42        S   83
## 146    1263       30       31       32       72       93       79        S  747
## 147    1063       70       75       73       28       48       53        S  767
## 148     484       47       45       53       17       27       30        S  252
## 149     259       14       12        8       10       20       26        S  678
## 150    2748       45       51       48      812      786      741        S  171
## 151      81        0        1        0       12       12       14        S  240
## 152     440       56       57       51        7       25       24        S   43
## 153      61        3        4        4        7        1        5        S  298
## 154    1372       36       35       46       62       60       52        S 1176
## 155     501        3        3        3       50       65       85        S  965
## 156     343       19       11        9       23       25       21        S  729
## 157     398       13       16       15       23       26       17        S 1346
## 158     351        9       10       12       19        9       13        S  318
## 159    1261      205      186      192       66       66       62        S  781
## 160     582       30       23       21       22       26       38        S   23
## 161    2303        5        6        9      122      165      176        S   22
## 162    1074      149      172      158       19       33       32        S 1041
## 163    1818       52       31       19      103      102      151        S  739
## 164     740       18       17       16       31       33       59        S 1245
## 165     670       20        9        5       17       27       43        S  697
## 166    1088        3        4        4      108      136      135        S  390
## 167     282       16       15        6       21       27       23        S  694
## 168       8        0        0        0       14        7        8        S  524
## 169     643       64       57       37       47       55       48        S 1080
## 170    1111       97       78       82       41       46       28        S 1042
## 171     144        6        6        7        4        3        3        S  339
## 172     279        6        3        4        6        3        0        S 1336
## 173     704       12       13        8       25       29       38        S  921
## 174     409        1        0        1       30       41       45        S  669
## 175    1387       77       75       73       53       56       30        S 1088
## 176     341      107      103      127       12       13       12        S 1071
## 177     555       12       14        7       37       43       59        S  441
## 178     125        0        0        0        3        8        7        S  442
## 179    1607        5        8        4      194      195      247        S  418
## 180     317       23       21       26      107       82       90        S  200
## 181     525       18       19       20       16       17       24        S   54
## 182      45       20       21       20        1        4        1        S 1110
## 183     421        2        0        5       27       35       24        S  130
## 184     169       13       12       17        8       10       13        S  149
## 185     137       97       95       80       12        9        9        S 1164
## 186    1018       22       23       19      121      103      115        S  393
## 187     189       13       13       15       16       12       13        S  861
## 188     394      188      186      190        6       22       12        S 1154
## 189     949       32       21       21      108       95      133        S  386
## 190     409        1        2        2       58       62       51        S  277
## 191     979       19       15       18       50       61       61        S  896
## 192     911      141      114      111       73       66       50        S 1196
## 193    1043        5        6        6      155      166      224        S  701
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## 194    780    150    137    135     36     51     39       S  762
## 195    560    120    115    114     22     25     27       S  774
## 196    143      0      1      1      6      5      9       S   87
## 197    461     20     22     22     20     17     15       S 1295
## 198   1689     26     30     35    119    113    102       S 1187
## 199    600     10      6      6     18     17     28       S  604
## 200    997     44     41     38     62     66     72       S  721
## 201   1839     43     44     27    104     91     98       S 1214
## 202   2113     20     19     16    205    176    282       S  482
## 203    330     93     86     85      5     12     11       S 1038
## 204    599      6      6      4     27     31     45       S  725
## 205    688     34     28     27     30     34     33       S  422
## 206   1240     67     72     82     66     68     61       S  872
## 207    320     11     16     19     17     16      9       S 1274
## 208    293     11      9     14     55     46     45       S  151
## 209    510      3      3      5     70     63     78       S  487
## 210    253     26     20     15     14      9     15       S  727
## 211    669      5      4      5     27     32     40       S  675
## 212    874     11      9     12    119    114    122       S  455
## 213    423    202    184    188     18     19     11       S 1109
## 214    149      9      6     10      7      4      7       S  352
## 215    693      1      1      4     52     47     66       S  899
## 216    186     14     11     13      6      8      8       S 1316
## 217   1135    196    181    152     55     67     46       S  832
## 218    269      2      2      2      3      6      3       S 1379
## 219    454     11     15     23     26     24     12       S  628
## 220    991      7     10      9     56     51     79       S  947
## 221    814     14     12     15     41     50     54       S  133
## 222    518     18     17     29     20     22     29       S  847
## 223    593     48     46     34     51     38     41       S 1086
## 224    177     85     83     81     11     11      9       S 1168
## 225    457      5      4      4     27     33     39       S  710
## 226    720     11      9     13     22     14     22       S 1359
## 227    430     17     16     17      9      9      9       S 1365
## 228    615     57     48     50     30     33     40       S  690
## 229    696     58     46     58     30     22     23       S  810
## 230   1082     12      9      8    124    130    146       S  484
## 231   1456      1      1      3    153    149    183       S  925
## 232    659      1     11     13     35     58     56       S 1096
## 233    332      7      6      9      5      7      5       S  585
## 234    833     26     29     24     53     47     55       S  243
## 235    530     24     28     36     32     32     31       S 1162
## 236   1424     95    106    109     64     70     48       S 1020
## 237     93     14     13     12     13      6     11       S  549
## 238    529    122    117    115     44     33     29       S 1108
## 239    466     13     15     15     24     29     42       S   65
## 240    197      0      0      0     39     33     52       S  695
## 241    848      5      6      5    120    103    103       S  395
## 242     29      2      1      1      6      2      1       S  304
## 243    176      0      0      0      6     11     11       S  348
## 244    188     21     26     26      7      5      7       S  325
## 245   1058     21     16     14     30     30     42       S  109
## 246    604      0      0      0     78    101    127       S  554
## 247    507    131    141    136     12     22     24       S 1217
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## 248   369  87  86  72    8    6    4  S  115
## 249   815  39  37  29   20   37   43  S  664
## 250   246  11   8  10   11   14   18  S 1292
## 251   268 113 109 111   13   11    9  S 1139
## 252   643 164 169 153   23   21   17  S 1181
## 253  1509  51  51  38  120  100   75  S 1082
## 254    25  14  13  15    0    2    0  S 1106
## 255  1081  33  29  29   36   52   47  S   75
## 256   874  66  61  51   70   82   65  S  996
## 257   477   6   4   9   17   12   27  S   81
## 258   857   3   3   2   90  111  125  S  413
## 259  1295   9   8   3  132  154  193  S  403
## 260   240  36  32  38   24   30   16  W  164
## 261  1441 300 322 290  330  327  330  W  325
## 262    29   9   8   9    0    1    1  W  283
## 263   670  26  25  24  505  365  316  W  145
## 264   612 108  97  89   41   43   32  W  345
## 265   677  65  59  48   37   56   36  W  338
## 266   499 289 308 310    9   41   32  W  200
## 267   198 124 124 123    9   15   10  W  323
## 268   675 443 467 443   12   17   18  W  210
## 269   210  99 100  97   13   29   17  W  228
## 270   781  11   9  10  121  106  114  W  300
## 271   465 133 108  96   88   87   66  W  254
## 272   222  39  38  40   10    7   11  W  150
## 273   575 124 129 134   39   40   43  W  380
## 274  2539  55  60  58 1960 1602 1468  W  142
## 275   442 271 292 293   10   31   27  W  405
## 276   354 255 287 273    6   20   13  W  240
## 277   121   8  15  12   11   11   13  W   11
## 278   138  56  75  52   13    6    8  W  103
## 279  1848  64  53  62  475  475  542  W  356
## 280  1196  36  30  30  163  150  180  W  322
## 281   451  65  72  71   20   43   30  W  149
## 282   484 214 216 209   13   31   13  W  114
## 283   439 179 181 194   13   37   32  W  218
## 284   124  29  35  30    9    7   12  W   97
## 285   270  44  44  40    8    8    9  W  186
## 286   584 335 353 350    9   20   18  W  232
## 287   597 128 141 137   23   47   43  W  194
## 288   422   1   0   0  143  164  137  W  378
## 289    19   2   2   3    2    0    0  W  105
## 290   876 114 109 109  139  134  120  W   32
## 291   417  65  64  66   47   69   55  W  353
## 292  1191  80  87  95   47   58   50  W  393
## 293  1618   8   5   7  271  274  317  W  366
## 294   145   0   0   0    5   12    8  W  395
## 295   856 127 140 120  107  109  101  W  371
## 296   534 208 205 191   59   67   63  W  259
## 297   856   5   4   4  171  143  151  W  394
## 298    34   3   2   2   15   15   17  W  295
## 299   617  79  81  83   98  112  106  W  148
## 300   625  67  79  66   25   39   33  W  112
##     weight
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## 90  10.23301
## 91  10.23301
## 92  10.23301
## 93  10.23301
## 94  10.23301
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## 97  10.23301
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```

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## 109 10.47619
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## 111 10.47619
## 112 10.47619
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## 117 10.47619
## 118 10.47619
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```

```
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```

```
## 271 10.29268
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## 298 10.29268
## 299 10.29268
## 300 10.29268
```

2.2 Spreadsheet calculation

2.2.1 Summarizing acre92 in each stratum

```
nh <- tapply (agstrat[, "acres92"], agstrat[,"region"], length)
sh <- tapply (agstrat[, "acres92"], agstrat[,"region"], sd)
ybarh <- tapply (agstrat[, "acres92"], agstrat[,"region"], mean)
# create a vector with external information
Nh <- c(NC = 1054, NE = 220, S= 1382, W = 422)

data.frame (Nh, nh, ybarh, sh)
```

```
##      Nh  nh     ybarh        sh
## NC 1054 103 300504.16 172099.34
## NE  220  21  97629.81  87449.83
## S  1382 135 211315.04 231489.71
## W   422  41 662295.51 629433.04
```

2.2.2 Estimates

```
N <- sum (Nh)
pi_h <- Nh/N
weighted_ybar_h <- ybarh * pi_h
```

```r
ybar <- sum(weighted_ybar_h)
var_h=(1-nh/Nh)*pi_h^2*sh^2/nh
library ("tibble")
tibble (`$N_h$`=Nh, nh=nh,pi_h, ybarh, sh=sh, var_h)
```

```
## # A tibble: 4 x 6
##   `$N_h$`        nh   pi_h     ybarh        sh      var_h
##     <dbl> <int[1d]>  <dbl> <dbl[1d]> <dbl[1d]>  <dbl[1d]>
## 1    1054       103 0.342    300504.   172099.  30423214.
## 2     220        21 0.0715    97630.    87450.   1682818.
## 3    1382       135 0.449    211315.   231490.  72204937.
## 4     422        41 0.137    662296.   629433. 163989261.
```

```r
seybar <- sqrt(sum((1-nh/Nh)*pi_h^2*sh^2/nh))
mem <- 1.96 * seybar
c(Est. = ybar, S.E. = seybar, ci.low = ybar - mem, ci.upp = ybar + mem)
```

```
##      Est.      S.E.    ci.low    ci.upp
## 295560.77  16379.87 263456.21 327665.32
```

2.3 Using the function "str_mean_estimate"

```r
nh <- tapply (agstrat[, "acres92"], agstrat[,"region"], length)
sh <- tapply (agstrat[, "acres92"], agstrat[,"region"], sd)
ybarh <- tapply (agstrat[, "acres92"], agstrat[,"region"], mean)
# create a vector with external information
Nh <- c(NC = 1054, NE = 220, S= 1382, W = 422)

## strata mean estimate
str_mean_estimate (ybarh, sh, nh, Nh)
```

```
##      Est.      S.E.    ci.low    ci.upp
## 295560.77  16379.87 263456.21 327665.32
```

```r
## population total estimate
str_mean_estimate (ybarh, sh, nh, Nh) * sum (Nh)
```

```
##       Est.       S.E.     ci.low     ci.upp
##  909736035   50417248  810918229 1008553842
```

2.4 Using the function "str_mean_estimate_data"

```r
## In the fucntion "str_mean_estimate_data", we can find the stratum size with the variable "weights":
tapply (agstrat$weight, agstrat$region, sum)
```

```
##   NC   NE    S    W
## 1054  220 1382  422
```

```r
## if the dataset contains a variable "weight"
str_mean_estimate_data (agstrat, y="acres92", stratum="region", weight="weight")
```

```
##      Est.      S.E.    ci.low    ci.upp
## 295560.77  16379.87 263456.21 327665.32
```

```r
## estimating the mean of the number of small farms in 1992
str_mean_estimate_data (agstrat, y="smallf92", stratum="region", weight="weight")
```

```
##      Est.      S.E.    ci.low    ci.upp
## 56.862794  7.201417 42.748016 70.977572
```

2.5 Comparing with SRS estimate

```r
agsrs <- read.csv ("data/agsrs.csv")
srs_mean_est(agsrs[, "acres92"], N=3078)
```

```
##      Est.      S.E.    ci.low    ci.upp
## 297897.05  18898.43 260706.26 335087.84
```

```r
## the ratio of estimated variance
(16379.87/18898.43)^2
```

```
## [1] 0.751224
```

```r
## percentage of reduction of variance of str estimates from that of SRS estimate
1- (16379.87/18898.43)^2
```

```
## [1] 0.248776
```

3 Allocation of stratum sample size

3.1 Analyzing seals.csv collected with stratified sampling

Lydersen and Ryg (1991) used stratification techniques to estimate ringed seal pop- ulations in Svalbard fjords. The 200 km2 study area was divided into three zones: Zone 1, outer Sassenfjorden, was covered with relatively new ice during the study period in March, 1990, and had little snow cover; Zone 3, Tempelfjorden, had a stable ice cover throughout the year; Zone 2, inner Sassenfjorden, was intermediate between the stable Zone 3 and the unstable Zone 1. Ringed seals need good ice to establish territories with breathing holes, and snow cover enables females to dig out birth lairs. Thus, it was thought that the three zones would have different seal densities. The investigators took a stratified random sample of 20% of the 200 1-km2 areas.

```r
###### ########

## load data
seals <- read.csv("data/seals.csv")
seals
```

```
##    zone holes
## 1     1     0
## 2     1     0
## 3     1     0
## 4     1     0
## 5     1     1
## 6     1     1
## 7     1     1
## 8     1     1
## 9     1     1
## 10    1     1
## 11    1     2
## 12    1     2
## 13    1     3
## 14    1     3
## 15    1     3
## 16    1     4
```

```
## 17    1     7
## 18    2     0
## 19    2     2
## 20    2     2
## 21    2     2
## 22    2     3
## 23    2     3
## 24    2     4
## 25    2     4
## 26    2     5
## 27    2     7
## 28    2     9
## 29    2    12
## 30    3     0
## 31    3     1
## 32    3     5
## 33    3     8
## 34    3    10
## 35    3    10
## 36    3    12
## 37    3    14
## 38    3    17
## 39    3    18
## 40    3    21
```

```r
# survey data summary in each stratum
nh <- as.vector(table(seals[,"zone"]))
sh <- tapply (seals[, "holes"], seals[,"zone"], sd)
ybarh <- tapply (seals[, "holes"], seals[,"zone"], mean)
Nh <- c(68,84,48)
data.frame (Nh,nh, ybarh, sh)
```

```
##   Nh nh     ybarh       sh
## 1 68 17  1.764706 1.821037
## 2 84 12  4.416667 3.396745
## 3 48 11 10.545455 6.787689
```

```r
str_mean_estimate (ybarh, sh, nh, Nh)
```

```
##      Est.      S.E.    ci.low    ci.upp
## 4.9859091 0.5901322 3.8292499 6.1425683
```

3.2 Neyman allocation of stratum sample size

```r
## assuming the cost of surving each zone is the same
Ch <- rep (1, 3)
Sh <- sh ## estimate Sh with sh
NhShDCh <- Nh * Sh / sqrt (Ch)

## the optimal allocation scheme for estimating the population total or means holes:
Lh <- NhShDCh / sum (NhShDCh)
data.frame(Ch,Nh, Sh,NhShDCh, Lh)
```

```
##   Ch Nh       Sh  NhShDCh        Lh
## 1  1 68 1.821037 123.8305 0.1684847
## 2  1 84 3.396745 285.3266 0.3882173
```

```
## 3  1 48 6.787689 325.8091 0.4432980
```

4 Simulation to Study the Efficiency of Stratified Sampling with Different Allocation

4.1 Using "Region" to Stratify

4.1.1 Read Population Data

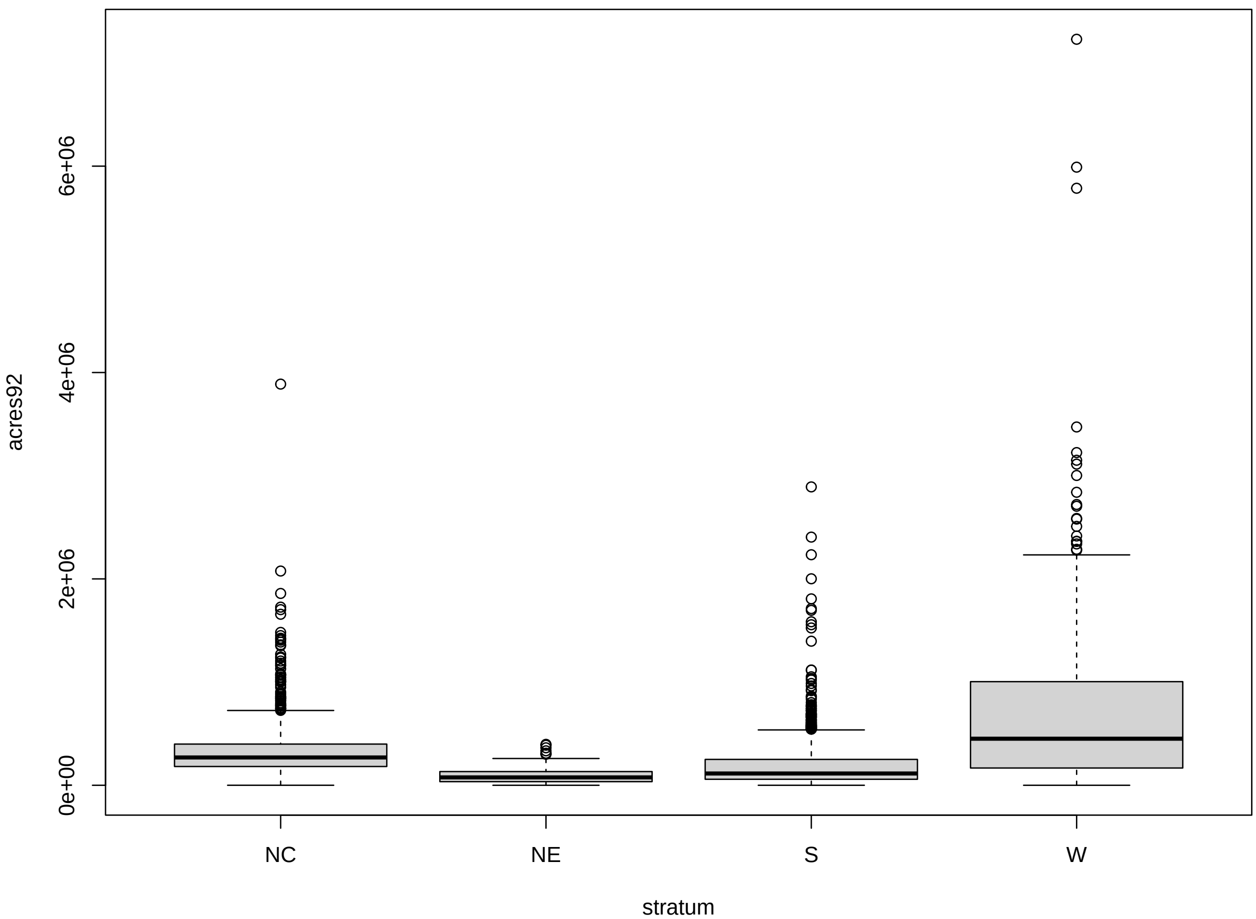
```
agpop <- read.csv ("data/agpop.csv")
agpop <- agpop[agpop$acres92 != -99, ] ## remove those counties with na
N <- nrow(agpop)
```

4.1.2 Define Stratum Variable

```
agpop$stratum <- agpop$region
## reorder agpop for the ease of using strata of "sampling" (very important)
agpop <- agpop[order (agpop$stratum), ]
```

Look at variance decomposition

```
boxplot (acres92 ~ stratum, data = agpop)
```



```r
anova(lm (agpop$acres92~agpop$stratum))
```

```
## Analysis of Variance Table
##
## Response: agpop$acres92
##                 Df    Sum Sq    Mean Sq F value    Pr(>F)
## agpop$stratum    3 1.0073e+14 3.3578e+13  226.73 < 2.2e-16 ***
## Residuals     3055 4.5243e+14 1.4810e+11
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Look at the R^2 of predicting "acres92" with "region".

```r
summary(lm (agpop$acres92~agpop$stratum))$r.squared
```

```
## [1] 0.1821031
```

4.1.3 Stratified Sampling with P2S allocation

```r
# doing one stratified sampling
Nh <- tapply (1:nrow(agpop), agpop$stratum, length)
nh <- round(Nh/sum (Nh)*300)
data.frame(Nh,nh)
```

```
##      Nh  nh
## NC 1052 103
## NE  213  21
## S  1376 135
## W   418  41
```

```r
nh
```

```
##  NC  NE   S   W
## 103  21 135  41
```

```r
## doing stratified sampling
strsample <- strata (agpop, "stratum", size = nh,  method = "srswor")
strsample
```

```
##      stratum ID_unit       Prob Stratum
## 12        NC      12 0.09790875       1
## 15        NC      15 0.09790875       1
## 23        NC      23 0.09790875       1
## 29        NC      29 0.09790875       1
## 36        NC      36 0.09790875       1
## 41        NC      41 0.09790875       1
## 53        NC      53 0.09790875       1
## 79        NC      79 0.09790875       1
## 93        NC      93 0.09790875       1
## 96        NC      96 0.09790875       1
## 104       NC     104 0.09790875       1
## 116       NC     116 0.09790875       1
## 118       NC     118 0.09790875       1
## 119       NC     119 0.09790875       1
## 133       NC     133 0.09790875       1
## 135       NC     135 0.09790875       1
## 145       NC     145 0.09790875       1
```

```
## 146          NC      146 0.09790875        1
## 150          NC      150 0.09790875        1
## 151          NC      151 0.09790875        1
## 155          NC      155 0.09790875        1
## 157          NC      157 0.09790875        1
## 160          NC      160 0.09790875        1
## 169          NC      169 0.09790875        1
## 181          NC      181 0.09790875        1
## 194          NC      194 0.09790875        1
## 195          NC      195 0.09790875        1
## 209          NC      209 0.09790875        1
## 211          NC      211 0.09790875        1
## 212          NC      212 0.09790875        1
## 220          NC      220 0.09790875        1
## 240          NC      240 0.09790875        1
## 245          NC      245 0.09790875        1
## 256          NC      256 0.09790875        1
## 266          NC      266 0.09790875        1
## 280          NC      280 0.09790875        1
## 285          NC      285 0.09790875        1
## 287          NC      287 0.09790875        1
## 289          NC      289 0.09790875        1
## 291          NC      291 0.09790875        1
## 301          NC      301 0.09790875        1
## 311          NC      311 0.09790875        1
## 314          NC      314 0.09790875        1
## 331          NC      331 0.09790875        1
## 335          NC      335 0.09790875        1
## 343          NC      343 0.09790875        1
## 359          NC      359 0.09790875        1
## 375          NC      375 0.09790875        1
## 377          NC      377 0.09790875        1
## 401          NC      401 0.09790875        1
## 408          NC      408 0.09790875        1
## 410          NC      410 0.09790875        1
## 415          NC      415 0.09790875        1
## 428          NC      428 0.09790875        1
## 449          NC      449 0.09790875        1
## 451          NC      451 0.09790875        1
## 455          NC      455 0.09790875        1
## 465          NC      465 0.09790875        1
## 466          NC      466 0.09790875        1
## 477          NC      477 0.09790875        1
## 479          NC      479 0.09790875        1
## 518          NC      518 0.09790875        1
## 557          NC      557 0.09790875        1
## 562          NC      562 0.09790875        1
## 572          NC      572 0.09790875        1
## 580          NC      580 0.09790875        1
## 598          NC      598 0.09790875        1
## 610          NC      610 0.09790875        1
## 624          NC      624 0.09790875        1
## 651          NC      651 0.09790875        1
## 666          NC      666 0.09790875        1
```

```
## 669        NC     669 0.09790875       1
## 677        NC     677 0.09790875       1
## 721        NC     721 0.09790875       1
## 729        NC     729 0.09790875       1
## 737        NC     737 0.09790875       1
## 756        NC     756 0.09790875       1
## 779        NC     779 0.09790875       1
## 798        NC     798 0.09790875       1
## 818        NC     818 0.09790875       1
## 840        NC     840 0.09790875       1
## 851        NC     851 0.09790875       1
## 853        NC     853 0.09790875       1
## 858        NC     858 0.09790875       1
## 859        NC     859 0.09790875       1
## 868        NC     868 0.09790875       1
## 886        NC     886 0.09790875       1
## 920        NC     920 0.09790875       1
## 924        NC     924 0.09790875       1
## 935        NC     935 0.09790875       1
## 943        NC     943 0.09790875       1
## 952        NC     952 0.09790875       1
## 957        NC     957 0.09790875       1
## 976        NC     976 0.09790875       1
## 979        NC     979 0.09790875       1
## 983        NC     983 0.09790875       1
## 985        NC     985 0.09790875       1
## 991        NC     991 0.09790875       1
## 993        NC     993 0.09790875       1
## 1007       NC    1007 0.09790875       1
## 1017       NC    1017 0.09790875       1
## 1038       NC    1038 0.09790875       1
## 1042       NC    1042 0.09790875       1
## 1054       NE    1054 0.09859155       2
## 1057       NE    1057 0.09859155       2
## 1058       NE    1058 0.09859155       2
## 1066       NE    1066 0.09859155       2
## 1075       NE    1075 0.09859155       2
## 1124       NE    1124 0.09859155       2
## 1136       NE    1136 0.09859155       2
## 1137       NE    1137 0.09859155       2
## 1138       NE    1138 0.09859155       2
## 1150       NE    1150 0.09859155       2
## 1156       NE    1156 0.09859155       2
## 1160       NE    1160 0.09859155       2
## 1188       NE    1188 0.09859155       2
## 1195       NE    1195 0.09859155       2
## 1207       NE    1207 0.09859155       2
## 1208       NE    1208 0.09859155       2
## 1224       NE    1224 0.09859155       2
## 1230       NE    1230 0.09859155       2
## 1245       NE    1245 0.09859155       2
## 1249       NE    1249 0.09859155       2
## 1250       NE    1250 0.09859155       2
## 1270        S    1270 0.09811047       3
```

```
## 1275        S    1275 0.09811047       3
## 1278        S    1278 0.09811047       3
## 1289        S    1289 0.09811047       3
## 1312        S    1312 0.09811047       3
## 1319        S    1319 0.09811047       3
## 1337        S    1337 0.09811047       3
## 1338        S    1338 0.09811047       3
## 1341        S    1341 0.09811047       3
## 1347        S    1347 0.09811047       3
## 1351        S    1351 0.09811047       3
## 1352        S    1352 0.09811047       3
## 1353        S    1353 0.09811047       3
## 1377        S    1377 0.09811047       3
## 1380        S    1380 0.09811047       3
## 1383        S    1383 0.09811047       3
## 1390        S    1390 0.09811047       3
## 1392        S    1392 0.09811047       3
## 1397        S    1397 0.09811047       3
## 1399        S    1399 0.09811047       3
## 1401        S    1401 0.09811047       3
## 1404        S    1404 0.09811047       3
## 1448        S    1448 0.09811047       3
## 1460        S    1460 0.09811047       3
## 1462        S    1462 0.09811047       3
## 1482        S    1482 0.09811047       3
## 1503        S    1503 0.09811047       3
## 1520        S    1520 0.09811047       3
## 1521        S    1521 0.09811047       3
## 1526        S    1526 0.09811047       3
## 1528        S    1528 0.09811047       3
## 1554        S    1554 0.09811047       3
## 1555        S    1555 0.09811047       3
## 1567        S    1567 0.09811047       3
## 1606        S    1606 0.09811047       3
## 1612        S    1612 0.09811047       3
## 1619        S    1619 0.09811047       3
## 1633        S    1633 0.09811047       3
## 1635        S    1635 0.09811047       3
## 1652        S    1652 0.09811047       3
## 1668        S    1668 0.09811047       3
## 1669        S    1669 0.09811047       3
## 1674        S    1674 0.09811047       3
## 1692        S    1692 0.09811047       3
## 1709        S    1709 0.09811047       3
## 1725        S    1725 0.09811047       3
## 1730        S    1730 0.09811047       3
## 1731        S    1731 0.09811047       3
## 1736        S    1736 0.09811047       3
## 1738        S    1738 0.09811047       3
## 1781        S    1781 0.09811047       3
## 1791        S    1791 0.09811047       3
## 1796        S    1796 0.09811047       3
## 1798        S    1798 0.09811047       3
## 1825        S    1825 0.09811047       3
```

```
## 1833        S    1833 0.09811047        3
## 1854        S    1854 0.09811047        3
## 1874        S    1874 0.09811047        3
## 1879        S    1879 0.09811047        3
## 1886        S    1886 0.09811047        3
## 1901        S    1901 0.09811047        3
## 1904        S    1904 0.09811047        3
## 1906        S    1906 0.09811047        3
## 1911        S    1911 0.09811047        3
## 1932        S    1932 0.09811047        3
## 1942        S    1942 0.09811047        3
## 1944        S    1944 0.09811047        3
## 1947        S    1947 0.09811047        3
## 1948        S    1948 0.09811047        3
## 1963        S    1963 0.09811047        3
## 1968        S    1968 0.09811047        3
## 1984        S    1984 0.09811047        3
## 1988        S    1988 0.09811047        3
## 1991        S    1991 0.09811047        3
## 1999        S    1999 0.09811047        3
## 2004        S    2004 0.09811047        3
## 2010        S    2010 0.09811047        3
## 2030        S    2030 0.09811047        3
## 2040        S    2040 0.09811047        3
## 2044        S    2044 0.09811047        3
## 2058        S    2058 0.09811047        3
## 2070        S    2070 0.09811047        3
## 2072        S    2072 0.09811047        3
## 2079        S    2079 0.09811047        3
## 2082        S    2082 0.09811047        3
## 2086        S    2086 0.09811047        3
## 2103        S    2103 0.09811047        3
## 2114        S    2114 0.09811047        3
## 2124        S    2124 0.09811047        3
## 2155        S    2155 0.09811047        3
## 2160        S    2160 0.09811047        3
## 2166        S    2166 0.09811047        3
## 2175        S    2175 0.09811047        3
## 2193        S    2193 0.09811047        3
## 2195        S    2195 0.09811047        3
## 2204        S    2204 0.09811047        3
## 2223        S    2223 0.09811047        3
## 2233        S    2233 0.09811047        3
## 2235        S    2235 0.09811047        3
## 2238        S    2238 0.09811047        3
## 2253        S    2253 0.09811047        3
## 2261        S    2261 0.09811047        3
## 2271        S    2271 0.09811047        3
## 2275        S    2275 0.09811047        3
## 2280        S    2280 0.09811047        3
## 2284        S    2284 0.09811047        3
## 2303        S    2303 0.09811047        3
## 2349        S    2349 0.09811047        3
## 2372        S    2372 0.09811047        3
```

```
## 2376        S     2376 0.09811047        3
## 2382        S     2382 0.09811047        3
## 2390        S     2390 0.09811047        3
## 2392        S     2392 0.09811047        3
## 2400        S     2400 0.09811047        3
## 2422        S     2422 0.09811047        3
## 2429        S     2429 0.09811047        3
## 2433        S     2433 0.09811047        3
## 2438        S     2438 0.09811047        3
## 2456        S     2456 0.09811047        3
## 2482        S     2482 0.09811047        3
## 2483        S     2483 0.09811047        3
## 2486        S     2486 0.09811047        3
## 2490        S     2490 0.09811047        3
## 2499        S     2499 0.09811047        3
## 2518        S     2518 0.09811047        3
## 2526        S     2526 0.09811047        3
## 2534        S     2534 0.09811047        3
## 2550        S     2550 0.09811047        3
## 2551        S     2551 0.09811047        3
## 2571        S     2571 0.09811047        3
## 2573        S     2573 0.09811047        3
## 2579        S     2579 0.09811047        3
## 2587        S     2587 0.09811047        3
## 2598        S     2598 0.09811047        3
## 2627        S     2627 0.09811047        3
## 2651        W     2651 0.09808612        4
## 2656        W     2656 0.09808612        4
## 2662        W     2662 0.09808612        4
## 2669        W     2669 0.09808612        4
## 2670        W     2670 0.09808612        4
## 2685        W     2685 0.09808612        4
## 2707        W     2707 0.09808612        4
## 2711        W     2711 0.09808612        4
## 2726        W     2726 0.09808612        4
## 2733        W     2733 0.09808612        4
## 2757        W     2757 0.09808612        4
## 2762        W     2762 0.09808612        4
## 2765        W     2765 0.09808612        4
## 2773        W     2773 0.09808612        4
## 2781        W     2781 0.09808612        4
## 2805        W     2805 0.09808612        4
## 2811        W     2811 0.09808612        4
## 2812        W     2812 0.09808612        4
## 2822        W     2822 0.09808612        4
## 2867        W     2867 0.09808612        4
## 2878        W     2878 0.09808612        4
## 2881        W     2881 0.09808612        4
## 2886        W     2886 0.09808612        4
## 2901        W     2901 0.09808612        4
## 2902        W     2902 0.09808612        4
## 2913        W     2913 0.09808612        4
## 2922        W     2922 0.09808612        4
## 2934        W     2934 0.09808612        4
```

```
## 2937       W    2937 0.09808612       4
## 2938       W    2938 0.09808612       4
## 2957       W    2957 0.09808612       4
## 2968       W    2968 0.09808612       4
## 2970       W    2970 0.09808612       4
## 2977       W    2977 0.09808612       4
## 2985       W    2985 0.09808612       4
## 3008       W    3008 0.09808612       4
## 3016       W    3016 0.09808612       4
## 3022       W    3022 0.09808612       4
## 3043       W    3043 0.09808612       4
## 3048       W    3048 0.09808612       4
## 3055       W    3055 0.09808612       4
```

```
## checking sampling results
table (strsample [,1])
```

```
##
##  NC  NE   S   W
## 103  21 135  41
```

```
# collecting data on sampled counties
agstrat <- agpop [strsample$ID_unit, ]
agstrat$weight <- 1/strsample$Prob

str_mean_estimate_data (agstrat, "acres92", "stratum", "weight")
```

```
##      Est.      S.E.    ci.low    ci.upp
## 337500.44  28795.76 281060.75 393940.12
```

Estimate with spreadsheet method for a double checking

```
## double checking the estimates
nh <- tapply (agstrat[, "acres92"], agstrat[,"region"], length)
sh <- tapply (agstrat[, "acres92"], agstrat[,"region"], sd)
ybarh <- tapply (agstrat[, "acres92"], agstrat[,"region"], mean)
# create a vector with external information
Nh <- tapply (1:nrow(agpop), agpop[,"region"], length)
## strata mean estimate
str_mean_estimate (ybarh, sh, nh, Nh)
```

```
##      Est.      S.E.    ci.low    ci.upp
## 337500.44  28795.76 281060.75 393940.12
```

4.1.4 Repeat stratified sampling with P2S allocation 2000 times

```
Nh <- tapply (1:nrow (agpop), agpop$stratum, length)
nh <- round(Nh/sum (Nh)*300) ## make sure the order matches Nh

nres <- 2000
str_p2s_simulated <- matrix (0, nres, 4)
for (i in 1:nres)
{
    ## doing stratified sampling
    strsample <- strata (agpop, "stratum", size = nh,  method = "srswor")
    agstrat <- agpop [strsample$ID_unit, ]
    agstrat$weight <- 1/strsample$Prob
```

```
    ## analyziing data
    str_p2s_simulated[i,] <- str_mean_estimate_data (agstrat, "acres92", "stratum", "weight")

}
```

4.1.5 Repeat stratified sampling with optimal allocation 2000 times

```
Nh <- tapply (agpop$acres92, agpop$stratum, length)

Sh <- tapply (agpop$acres92, agpop$stratum, sd)
nh_opt <- round((Nh*Sh)/sum (Nh*Sh) * 300);nh_opt
```

```
##  NC  NE   S   W
##  87   5 102 106
```

```
data.frame(Nh,Sh,nh_opt)
```

```
##      Nh       Sh nh_opt
## NC 1052 271188.0     87
## NE  213  78906.2      5
## S  1376 244132.0    102
## W   418 836613.6    106
```

```
nres <- 2000
str_neyman_simulated <- matrix (0, nres, 4)
for (i in 1:nres)
{
    ## doing stratified sampling
    strsample <- strata (agpop, "stratum", size = nh_opt,  method = "srswor")
    # collecting data on sampled counties
    agstrat <- agpop [strsample$ID_unit, ]
    agstrat$weight <- 1/strsample$Prob

    str_neyman_simulated[i,] <- str_mean_estimate_data (agstrat, "acres92", "stratum", "weight")

}
```

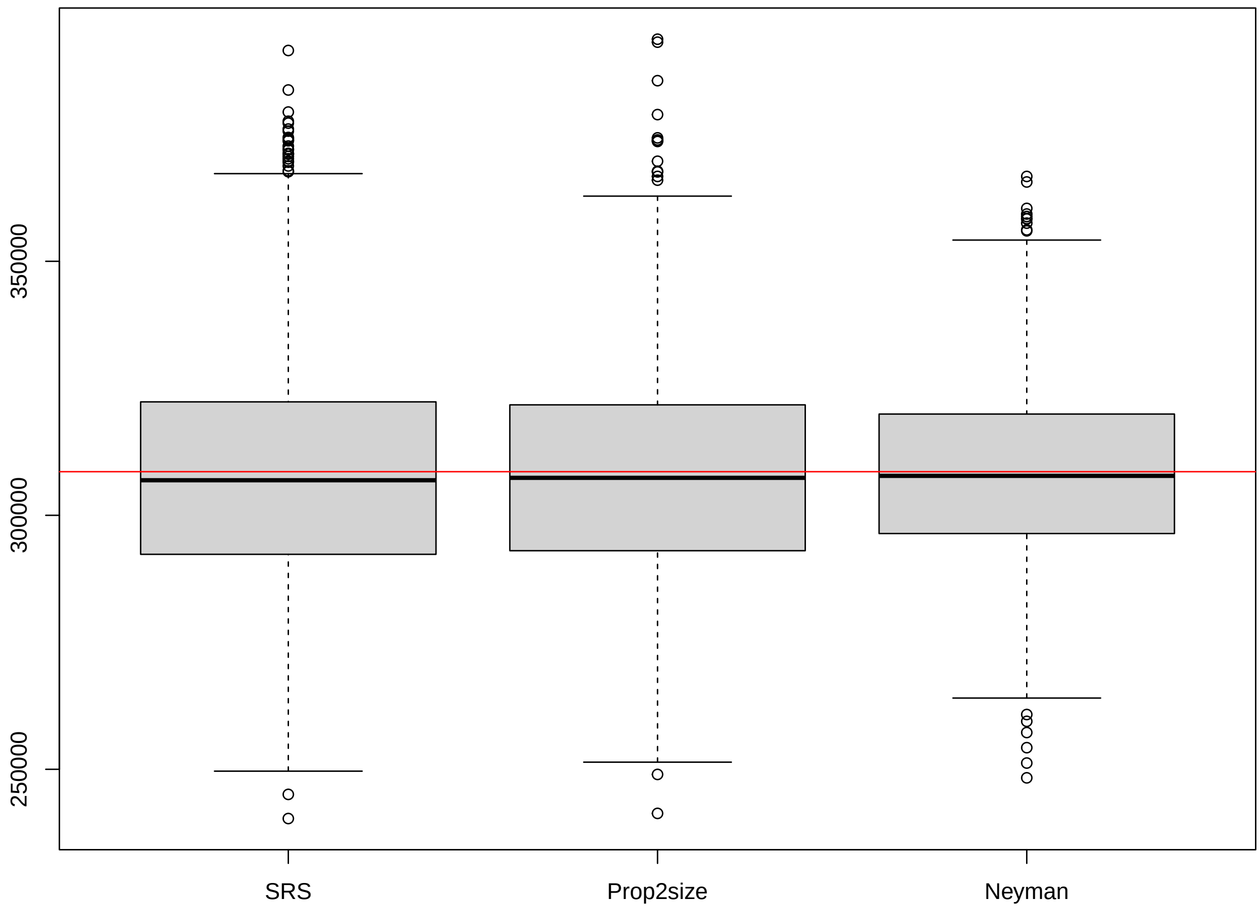
4.1.6 Repeat simple random sampling 2000 times

```
nres <- 2000
srs_simulated <- matrix (0, nres, 4)
for (i in 1:nres)
{
    ## doing stratified sampling
    srs <- sample (sum(Nh), sum (nh))
    # collecting data on sampled counties
    agsrs <- agpop [srs, ]
    srs_simulated[i,] <- srs_mean_est (agsrs[, "acres92"], N= sum(Nh))

}
```

4.1.7 Compare the efficiency of different methods

```r
sim_results_str_region <- data.frame("SRS"=srs_simulated[,1],
                           "Prop2size"=str_p2s_simulated[,1],
                           "Neyman"=str_neyman_simulated[,1])
boxplot (sim_results_str_region)
abline (h = mean (agpop$acres92), col = "red")
```




```r
sapply (sim_results_str_region, mean) -> sim_means
sapply (sim_results_str_region, var) -> sim_var

sim_var/sim_var[1] -> sim_var_relative

#Percentage of reduction of variances of estimates compared to SRS

1-sim_var/sim_var[1] -> sim_var_reduction

cbind("Mean"=sim_means, "Variance"=sim_var, "Relative Variance"= sim_var_relative, "Percentage of Varia
```

```
##                Mean  Variance Relative Variance Percentage of Variance Reduction
## SRS       308075.0 530066896         1.0000000                       0.0000000
## Prop2size 308182.8 447482662         0.8442004                       0.1557996
## Neyman    308180.5 297403782         0.5610684                       0.4389316
```

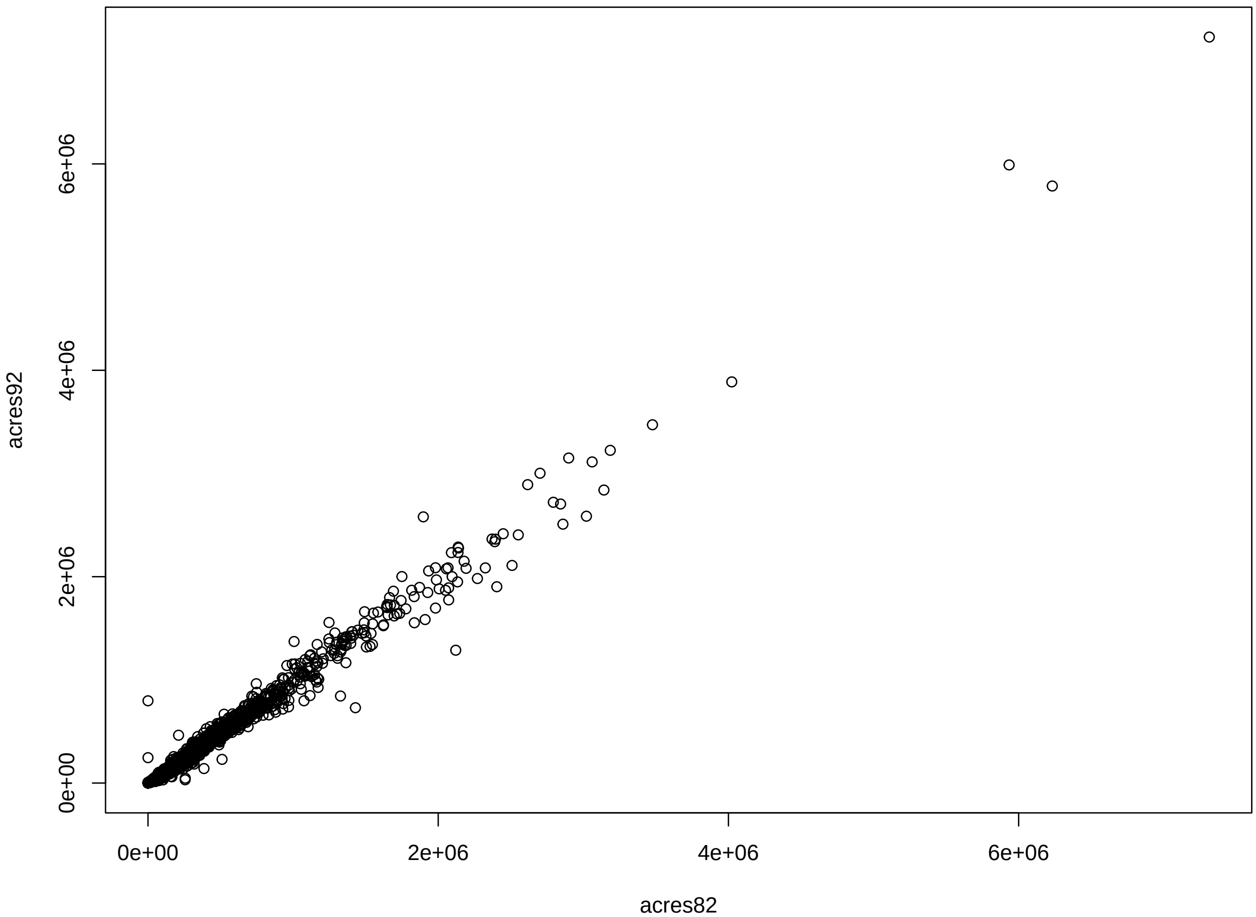
4.2 Using "acres82" to Define Strata

4.2.1 Read Population Data

```
agpop <- read.csv ("data/agpop.csv")
agpop <- agpop[agpop$acres92 != -99, ] ## remove those counties with na
N <- nrow(agpop)
```

4.2.2 Define Stratum Variable with Quantiles of "acres82"

```
plot (acres92~acres82, data = agpop)
```




```
summary (lm(acres92~acres82, data = agpop))
```

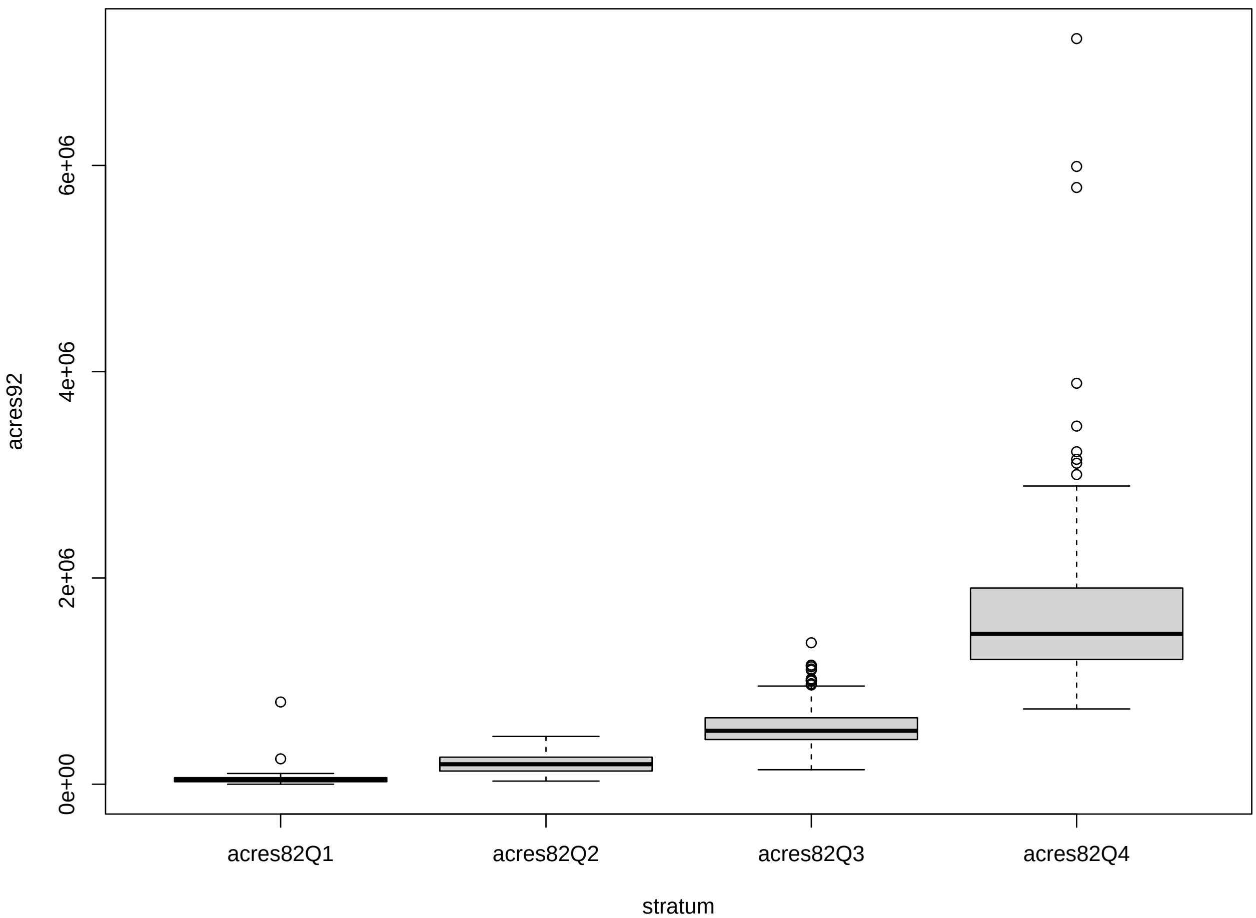
```
##
## Call:
## lm(formula = acres92 ~ acres82, data = agpop)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -786951  -11680    -548    8907  804356
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -7.142e+03  1.159e+03  -6.165 7.99e-10 ***
```

```
## acres82      9.813e-01  2.157e-03 455.015  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 51310 on 3057 degrees of freedom
## Multiple R-squared:  0.9854, Adjusted R-squared:  0.9854
## F-statistic: 2.07e+05 on 1 and 3057 DF,  p-value: < 2.2e-16
```

```
agpop$stratum <- cut(agpop$acres82,
                     breaks = quantile (agpop$acres82,
                                        probs = c(0,0.25,0.75,0.95,1)),
                     include.lowest =  T)
agpop$stratum <- mapvalues(agpop$stratum,
                          from = (sort(unique (agpop$stratum))),
                          to= paste0("acres82",c("Q1", "Q2", "Q3", "Q4")))
agpop <- agpop[order(agpop$stratum), ]
```

Look at variance decomposition

```
boxplot (acres92 ~ stratum, data = agpop)
```




```
anova(lm (agpop$acres92~agpop$stratum))
```

```
## Analysis of Variance Table
##
## Response: agpop$acres92
##                 Df     Sum Sq    Mean Sq F value    Pr(>F)
```

```
## agpop$stratum    3 4.0896e+14 1.3632e+14  2887.9 < 2.2e-16 ***
## Residuals     3055 1.4421e+14 4.7204e+10
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Look at the R^2 of predicting "acres92" with "acres82" quantile.

```
summary(lm (agpop$acres92~agpop$stratum))$r.squared
```

```
## [1] 0.7393047
```

4.2.3 Stratified sampling with P2S allocation

```
# doing one stratified sampling
Nh <- tapply (1:nrow(agpop), agpop$stratum, length)
nh <- round(Nh/sum (Nh)*300)
nh
```

```
## acres82Q1 acres82Q2 acres82Q3 acres82Q4
##        75       150        60        15
```

```
## doing stratified sampling
strsample <- strata (agpop, "stratum", size = nh,  method = "srswor")
strsample
```

```
##        stratum ID_unit       Prob Stratum
## 4    acres82Q1       4 0.09803922       1
## 12   acres82Q1      12 0.09803922       1
## 31   acres82Q1      31 0.09803922       1
## 38   acres82Q1      38 0.09803922       1
## 46   acres82Q1      46 0.09803922       1
## 51   acres82Q1      51 0.09803922       1
## 55   acres82Q1      55 0.09803922       1
## 56   acres82Q1      56 0.09803922       1
## 62   acres82Q1      62 0.09803922       1
## 70   acres82Q1      70 0.09803922       1
## 72   acres82Q1      72 0.09803922       1
## 73   acres82Q1      73 0.09803922       1
## 93   acres82Q1      93 0.09803922       1
## 94   acres82Q1      94 0.09803922       1
## 106  acres82Q1     106 0.09803922       1
## 120  acres82Q1     120 0.09803922       1
## 132  acres82Q1     132 0.09803922       1
## 136  acres82Q1     136 0.09803922       1
## 145  acres82Q1     145 0.09803922       1
## 146  acres82Q1     146 0.09803922       1
## 150  acres82Q1     150 0.09803922       1
## 152  acres82Q1     152 0.09803922       1
## 156  acres82Q1     156 0.09803922       1
## 163  acres82Q1     163 0.09803922       1
## 167  acres82Q1     167 0.09803922       1
## 180  acres82Q1     180 0.09803922       1
## 185  acres82Q1     185 0.09803922       1
## 187  acres82Q1     187 0.09803922       1
## 213  acres82Q1     213 0.09803922       1
## 218  acres82Q1     218 0.09803922       1
```

```
## 226  acres82Q1     226 0.09803922       1
## 230  acres82Q1     230 0.09803922       1
## 231  acres82Q1     231 0.09803922       1
## 232  acres82Q1     232 0.09803922       1
## 257  acres82Q1     257 0.09803922       1
## 267  acres82Q1     267 0.09803922       1
## 284  acres82Q1     284 0.09803922       1
## 297  acres82Q1     297 0.09803922       1
## 302  acres82Q1     302 0.09803922       1
## 309  acres82Q1     309 0.09803922       1
## 327  acres82Q1     327 0.09803922       1
## 339  acres82Q1     339 0.09803922       1
## 343  acres82Q1     343 0.09803922       1
## 351  acres82Q1     351 0.09803922       1
## 367  acres82Q1     367 0.09803922       1
## 379  acres82Q1     379 0.09803922       1
## 384  acres82Q1     384 0.09803922       1
## 389  acres82Q1     389 0.09803922       1
## 397  acres82Q1     397 0.09803922       1
## 410  acres82Q1     410 0.09803922       1
## 415  acres82Q1     415 0.09803922       1
## 443  acres82Q1     443 0.09803922       1
## 465  acres82Q1     465 0.09803922       1
## 470  acres82Q1     470 0.09803922       1
## 472  acres82Q1     472 0.09803922       1
## 493  acres82Q1     493 0.09803922       1
## 519  acres82Q1     519 0.09803922       1
## 523  acres82Q1     523 0.09803922       1
## 533  acres82Q1     533 0.09803922       1
## 548  acres82Q1     548 0.09803922       1
## 557  acres82Q1     557 0.09803922       1
## 563  acres82Q1     563 0.09803922       1
## 579  acres82Q1     579 0.09803922       1
## 590  acres82Q1     590 0.09803922       1
## 599  acres82Q1     599 0.09803922       1
## 611  acres82Q1     611 0.09803922       1
## 617  acres82Q1     617 0.09803922       1
## 629  acres82Q1     629 0.09803922       1
## 650  acres82Q1     650 0.09803922       1
## 654  acres82Q1     654 0.09803922       1
## 681  acres82Q1     681 0.09803922       1
## 687  acres82Q1     687 0.09803922       1
## 716  acres82Q1     716 0.09803922       1
## 724  acres82Q1     724 0.09803922       1
## 727  acres82Q1     727 0.09803922       1
## 801  acres82Q2     801 0.09810334       2
## 813  acres82Q2     813 0.09810334       2
## 845  acres82Q2     845 0.09810334       2
## 886  acres82Q2     886 0.09810334       2
## 894  acres82Q2     894 0.09810334       2
## 900  acres82Q2     900 0.09810334       2
## 901  acres82Q2     901 0.09810334       2
## 903  acres82Q2     903 0.09810334       2
## 906  acres82Q2     906 0.09810334       2
```

```
## 920  acres82Q2     920 0.09810334        2
## 932  acres82Q2     932 0.09810334        2
## 966  acres82Q2     966 0.09810334        2
## 972  acres82Q2     972 0.09810334        2
## 989  acres82Q2     989 0.09810334        2
## 995  acres82Q2     995 0.09810334        2
## 1019 acres82Q2    1019 0.09810334        2
## 1024 acres82Q2    1024 0.09810334        2
## 1031 acres82Q2    1031 0.09810334        2
## 1052 acres82Q2    1052 0.09810334        2
## 1064 acres82Q2    1064 0.09810334        2
## 1083 acres82Q2    1083 0.09810334        2
## 1086 acres82Q2    1086 0.09810334        2
## 1100 acres82Q2    1100 0.09810334        2
## 1106 acres82Q2    1106 0.09810334        2
## 1108 acres82Q2    1108 0.09810334        2
## 1112 acres82Q2    1112 0.09810334        2
## 1130 acres82Q2    1130 0.09810334        2
## 1134 acres82Q2    1134 0.09810334        2
## 1145 acres82Q2    1145 0.09810334        2
## 1157 acres82Q2    1157 0.09810334        2
## 1158 acres82Q2    1158 0.09810334        2
## 1179 acres82Q2    1179 0.09810334        2
## 1182 acres82Q2    1182 0.09810334        2
## 1193 acres82Q2    1193 0.09810334        2
## 1194 acres82Q2    1194 0.09810334        2
## 1198 acres82Q2    1198 0.09810334        2
## 1202 acres82Q2    1202 0.09810334        2
## 1218 acres82Q2    1218 0.09810334        2
## 1220 acres82Q2    1220 0.09810334        2
## 1228 acres82Q2    1228 0.09810334        2
## 1234 acres82Q2    1234 0.09810334        2
## 1235 acres82Q2    1235 0.09810334        2
## 1245 acres82Q2    1245 0.09810334        2
## 1247 acres82Q2    1247 0.09810334        2
## 1248 acres82Q2    1248 0.09810334        2
## 1262 acres82Q2    1262 0.09810334        2
## 1263 acres82Q2    1263 0.09810334        2
## 1264 acres82Q2    1264 0.09810334        2
## 1265 acres82Q2    1265 0.09810334        2
## 1296 acres82Q2    1296 0.09810334        2
## 1303 acres82Q2    1303 0.09810334        2
## 1317 acres82Q2    1317 0.09810334        2
## 1324 acres82Q2    1324 0.09810334        2
## 1332 acres82Q2    1332 0.09810334        2
## 1367 acres82Q2    1367 0.09810334        2
## 1381 acres82Q2    1381 0.09810334        2
## 1382 acres82Q2    1382 0.09810334        2
## 1386 acres82Q2    1386 0.09810334        2
## 1390 acres82Q2    1390 0.09810334        2
## 1392 acres82Q2    1392 0.09810334        2
## 1395 acres82Q2    1395 0.09810334        2
## 1427 acres82Q2    1427 0.09810334        2
## 1430 acres82Q2    1430 0.09810334        2
```

```
## 1437 acres82Q2    1437 0.09810334       2
## 1447 acres82Q2    1447 0.09810334       2
## 1451 acres82Q2    1451 0.09810334       2
## 1464 acres82Q2    1464 0.09810334       2
## 1474 acres82Q2    1474 0.09810334       2
## 1478 acres82Q2    1478 0.09810334       2
## 1485 acres82Q2    1485 0.09810334       2
## 1486 acres82Q2    1486 0.09810334       2
## 1487 acres82Q2    1487 0.09810334       2
## 1498 acres82Q2    1498 0.09810334       2
## 1500 acres82Q2    1500 0.09810334       2
## 1504 acres82Q2    1504 0.09810334       2
## 1526 acres82Q2    1526 0.09810334       2
## 1534 acres82Q2    1534 0.09810334       2
## 1553 acres82Q2    1553 0.09810334       2
## 1557 acres82Q2    1557 0.09810334       2
## 1559 acres82Q2    1559 0.09810334       2
## 1573 acres82Q2    1573 0.09810334       2
## 1581 acres82Q2    1581 0.09810334       2
## 1592 acres82Q2    1592 0.09810334       2
## 1607 acres82Q2    1607 0.09810334       2
## 1611 acres82Q2    1611 0.09810334       2
## 1617 acres82Q2    1617 0.09810334       2
## 1627 acres82Q2    1627 0.09810334       2
## 1634 acres82Q2    1634 0.09810334       2
## 1639 acres82Q2    1639 0.09810334       2
## 1668 acres82Q2    1668 0.09810334       2
## 1679 acres82Q2    1679 0.09810334       2
## 1682 acres82Q2    1682 0.09810334       2
## 1683 acres82Q2    1683 0.09810334       2
## 1688 acres82Q2    1688 0.09810334       2
## 1689 acres82Q2    1689 0.09810334       2
## 1696 acres82Q2    1696 0.09810334       2
## 1697 acres82Q2    1697 0.09810334       2
## 1701 acres82Q2    1701 0.09810334       2
## 1725 acres82Q2    1725 0.09810334       2
## 1735 acres82Q2    1735 0.09810334       2
## 1752 acres82Q2    1752 0.09810334       2
## 1771 acres82Q2    1771 0.09810334       2
## 1799 acres82Q2    1799 0.09810334       2
## 1802 acres82Q2    1802 0.09810334       2
## 1803 acres82Q2    1803 0.09810334       2
## 1808 acres82Q2    1808 0.09810334       2
## 1813 acres82Q2    1813 0.09810334       2
## 1818 acres82Q2    1818 0.09810334       2
## 1831 acres82Q2    1831 0.09810334       2
## 1842 acres82Q2    1842 0.09810334       2
## 1852 acres82Q2    1852 0.09810334       2
## 1854 acres82Q2    1854 0.09810334       2
## 1870 acres82Q2    1870 0.09810334       2
## 1877 acres82Q2    1877 0.09810334       2
## 1878 acres82Q2    1878 0.09810334       2
## 1915 acres82Q2    1915 0.09810334       2
## 1926 acres82Q2    1926 0.09810334       2
```

```
## 1939 acres82Q2    1939 0.09810334       2
## 1943 acres82Q2    1943 0.09810334       2
## 1951 acres82Q2    1951 0.09810334       2
## 1952 acres82Q2    1952 0.09810334       2
## 1953 acres82Q2    1953 0.09810334       2
## 1967 acres82Q2    1967 0.09810334       2
## 2000 acres82Q2    2000 0.09810334       2
## 2005 acres82Q2    2005 0.09810334       2
## 2011 acres82Q2    2011 0.09810334       2
## 2017 acres82Q2    2017 0.09810334       2
## 2046 acres82Q2    2046 0.09810334       2
## 2061 acres82Q2    2061 0.09810334       2
## 2066 acres82Q2    2066 0.09810334       2
## 2087 acres82Q2    2087 0.09810334       2
## 2097 acres82Q2    2097 0.09810334       2
## 2098 acres82Q2    2098 0.09810334       2
## 2099 acres82Q2    2099 0.09810334       2
## 2102 acres82Q2    2102 0.09810334       2
## 2104 acres82Q2    2104 0.09810334       2
## 2139 acres82Q2    2139 0.09810334       2
## 2149 acres82Q2    2149 0.09810334       2
## 2158 acres82Q2    2158 0.09810334       2
## 2160 acres82Q2    2160 0.09810334       2
## 2171 acres82Q2    2171 0.09810334       2
## 2186 acres82Q2    2186 0.09810334       2
## 2221 acres82Q2    2221 0.09810334       2
## 2223 acres82Q2    2223 0.09810334       2
## 2230 acres82Q2    2230 0.09810334       2
## 2252 acres82Q2    2252 0.09810334       2
## 2267 acres82Q2    2267 0.09810334       2
## 2280 acres82Q2    2280 0.09810334       2
## 2290 acres82Q2    2290 0.09810334       2
## 2294 acres82Q2    2294 0.09810334       2
## 2302 acres82Q3    2302 0.09803922       3
## 2311 acres82Q3    2311 0.09803922       3
## 2317 acres82Q3    2317 0.09803922       3
## 2328 acres82Q3    2328 0.09803922       3
## 2338 acres82Q3    2338 0.09803922       3
## 2339 acres82Q3    2339 0.09803922       3
## 2341 acres82Q3    2341 0.09803922       3
## 2361 acres82Q3    2361 0.09803922       3
## 2380 acres82Q3    2380 0.09803922       3
## 2384 acres82Q3    2384 0.09803922       3
## 2385 acres82Q3    2385 0.09803922       3
## 2421 acres82Q3    2421 0.09803922       3
## 2422 acres82Q3    2422 0.09803922       3
## 2425 acres82Q3    2425 0.09803922       3
## 2446 acres82Q3    2446 0.09803922       3
## 2462 acres82Q3    2462 0.09803922       3
## 2493 acres82Q3    2493 0.09803922       3
## 2511 acres82Q3    2511 0.09803922       3
## 2515 acres82Q3    2515 0.09803922       3
## 2516 acres82Q3    2516 0.09803922       3
## 2521 acres82Q3    2521 0.09803922       3
```

```
## 2539 acres82Q3    2539 0.09803922       3
## 2565 acres82Q3    2565 0.09803922       3
## 2568 acres82Q3    2568 0.09803922       3
## 2580 acres82Q3    2580 0.09803922       3
## 2624 acres82Q3    2624 0.09803922       3
## 2631 acres82Q3    2631 0.09803922       3
## 2639 acres82Q3    2639 0.09803922       3
## 2654 acres82Q3    2654 0.09803922       3
## 2658 acres82Q3    2658 0.09803922       3
## 2670 acres82Q3    2670 0.09803922       3
## 2672 acres82Q3    2672 0.09803922       3
## 2681 acres82Q3    2681 0.09803922       3
## 2682 acres82Q3    2682 0.09803922       3
## 2690 acres82Q3    2690 0.09803922       3
## 2705 acres82Q3    2705 0.09803922       3
## 2708 acres82Q3    2708 0.09803922       3
## 2711 acres82Q3    2711 0.09803922       3
## 2714 acres82Q3    2714 0.09803922       3
## 2722 acres82Q3    2722 0.09803922       3
## 2735 acres82Q3    2735 0.09803922       3
## 2749 acres82Q3    2749 0.09803922       3
## 2763 acres82Q3    2763 0.09803922       3
## 2767 acres82Q3    2767 0.09803922       3
## 2768 acres82Q3    2768 0.09803922       3
## 2782 acres82Q3    2782 0.09803922       3
## 2790 acres82Q3    2790 0.09803922       3
## 2797 acres82Q3    2797 0.09803922       3
## 2799 acres82Q3    2799 0.09803922       3
## 2819 acres82Q3    2819 0.09803922       3
## 2822 acres82Q3    2822 0.09803922       3
## 2824 acres82Q3    2824 0.09803922       3
## 2831 acres82Q3    2831 0.09803922       3
## 2844 acres82Q3    2844 0.09803922       3
## 2850 acres82Q3    2850 0.09803922       3
## 2851 acres82Q3    2851 0.09803922       3
## 2886 acres82Q3    2886 0.09803922       3
## 2896 acres82Q3    2896 0.09803922       3
## 2901 acres82Q3    2901 0.09803922       3
## 2905 acres82Q3    2905 0.09803922       3
## 2922 acres82Q4    2922 0.09803922       4
## 2929 acres82Q4    2929 0.09803922       4
## 2932 acres82Q4    2932 0.09803922       4
## 2934 acres82Q4    2934 0.09803922       4
## 2950 acres82Q4    2950 0.09803922       4
## 2957 acres82Q4    2957 0.09803922       4
## 2963 acres82Q4    2963 0.09803922       4
## 2975 acres82Q4    2975 0.09803922       4
## 2979 acres82Q4    2979 0.09803922       4
## 2993 acres82Q4    2993 0.09803922       4
## 2994 acres82Q4    2994 0.09803922       4
## 3008 acres82Q4    3008 0.09803922       4
## 3012 acres82Q4    3012 0.09803922       4
## 3019 acres82Q4    3019 0.09803922       4
## 3036 acres82Q4    3036 0.09803922       4
```

```
## checking sampling results
table (strsample [,1])
```

```
##
## acres82Q1 acres82Q2 acres82Q3 acres82Q4
##        75       150        60        15
```

```
# collecting data on sampled counties
agstrat <- agpop [strsample$ID_unit, ]
agstrat$weight <- 1/strsample$Prob

str_mean_estimate_data (agstrat, "acres92", "stratum", "weight")
```

```
##       Est.        S.E.      ci.low     ci.upp
## 306423.020   8086.189 290574.091 322271.950
```

4.2.4 Repeat stratified sampling with P2S allocation 2000 times

```
Nh <- tapply (1:nrow (agpop), agpop$stratum, length)
nh <- round(Nh/sum (Nh)*300) ## make sure the order matches Nh
data.frame(Nh, nh)
```

```
##             Nh  nh
## acres82Q1  765  75
## acres82Q2 1529 150
## acres82Q3  612  60
## acres82Q4  153  15
```

```
nres <- 2000
str_p2s_simulated <- matrix (0, nres, 4)
for (i in 1:nres)
{
    ## doing stratified sampling
    strsample <- strata (agpop, "stratum", size = nh,  method = "srswor")
    agstrat <- agpop [strsample$ID_unit, ]
    agstrat$weight <- 1/strsample$Prob
    ## analyziing data
    str_p2s_simulated[i,] <- str_mean_estimate_data (agstrat, "acres92", "stratum", "weight")

}
```

4.2.5 Repeat stratified sampling with optimal allocation 2000 times

```
Nh <- tapply (1:nrow (agpop), agpop$stratum, length)
# find order of stratum
# unique (agpop$stratum)
Sh <- tapply (agpop$acres92, agpop$stratum, sd)
nh_opt <- round((Nh*Sh)/sum (Nh*Sh) * 300);nh_opt
```

```
## acres82Q1 acres82Q2 acres82Q3 acres82Q4
##        22        98        77       103
```

```
data.frame(Nh,Sh,nh_opt)
```

```
##             Nh       Sh nh_opt
## acres82Q1  765 37409.71     22
```

```
## acres82Q2 1529  83714.96     98
## acres82Q3  612 162774.52     77
## acres82Q4  153 874495.84    103
```

```
nres <- 2000
str_neyman_simulated <- matrix (0, nres, 4)
for (i in 1:nres)
{
    ## doing stratified sampling
    strsample <- strata (agpop, "stratum", size = nh_opt,  method = "srswor")
    # collecting data on sampled counties
    agstrat <- agpop [strsample$ID_unit, ]
    agstrat$weight <- 1/strsample$Prob

    str_neyman_simulated[i,] <- str_mean_estimate_data (agstrat, "acres92", "stratum", "weight")

}
```

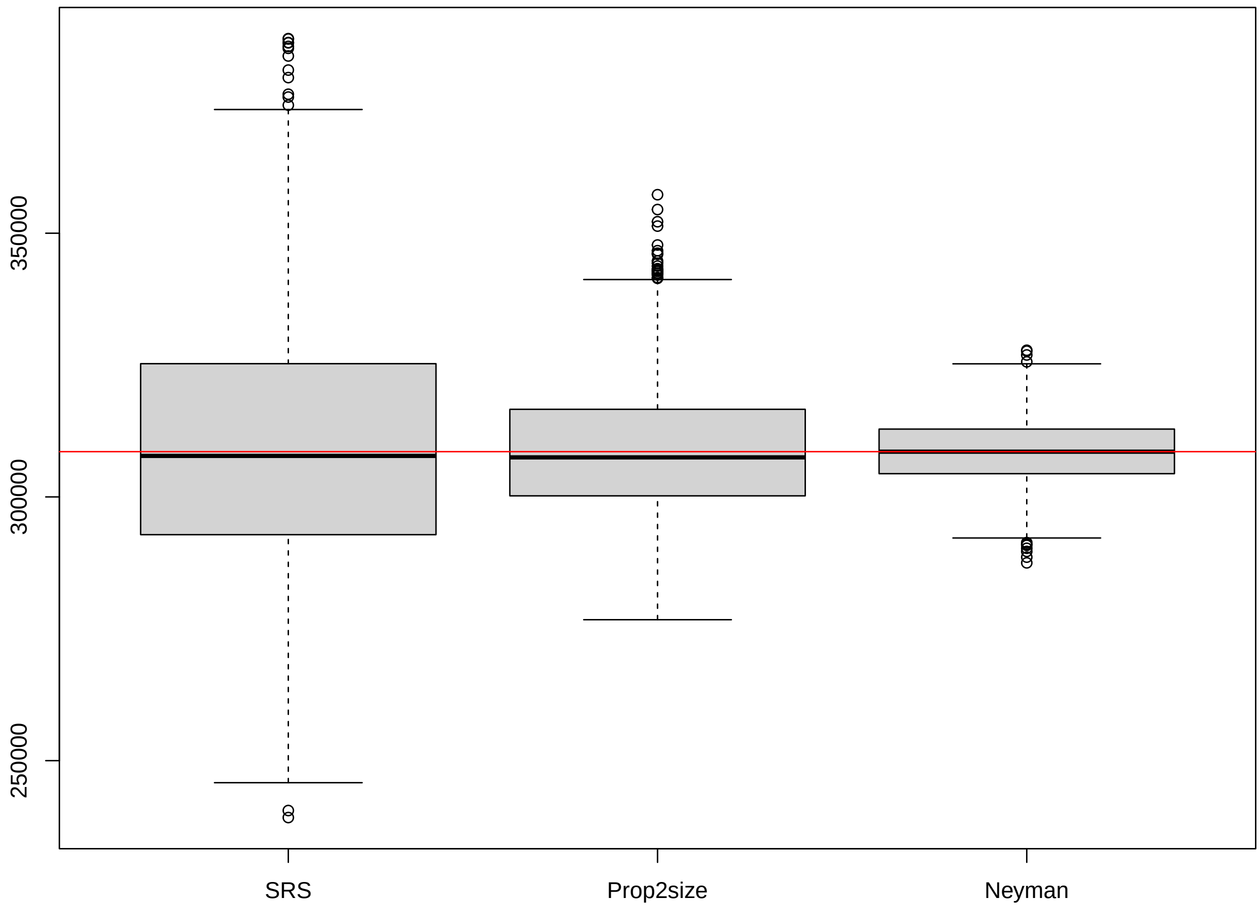
4.2.6 Repeat simple random sampling 2000 times

```
nres <- 2000
srs_simulated <- matrix (0, nres, 4)
for (i in 1:nres)
{
    ## doing stratified sampling
    srs <- sample (sum(Nh), sum (nh))
    # collecting data on sampled counties
    agsrs <- agpop [srs, ]
    srs_simulated[i,] <- srs_mean_est (agsrs[, "acres92"], N= sum(Nh))

}
```

4.2.7 Compare the efficiency of different methods

```
sim_results_str_acres82 <- data.frame("SRS"=srs_simulated[,1],
                      "Prop2size"=str_p2s_simulated[,1],
                      "Neyman"=str_neyman_simulated[,1])
boxplot (sim_results_str_acres82)
abline (h = mean (agpop$acres92), col = "red")
```




```r
sapply (sim_results_str_acres82, mean) -> sim_means
sapply (sim_results_str_acres82, var) -> sim_var

sim_var/sim_var[1] -> sim_var_relative

#Percentage of reduction of variances of estimates compared to SRS

1-sim_var/sim_var[1] -> sim_var_reduction

cbind("Mean"=sim_means, "Variance"=sim_var, "Relative Variance"= sim_var_relative, "Percentage of Varia
```

```
##                 Mean  Variance Relative Variance Percentage of Variance Reduction
## SRS         309395.3 563980266        1.00000000                        0.0000000
## Prop2size   308903.1 150620233        0.26706650                        0.7329335
## Neyman      308585.9  38522185        0.06830414                        0.9316959
```