SAS macro to generate Network Balanced Type II Designs (NetBD2) for multi-location agroforestry trial

Developed By

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Sometimes a single continuous piece of land may not be available at one location to the researcher for implementation of the designs. In such situations, it will be preferable to have suitable designs which can be implemented in multiple locations despite the limitations associated with the available land. A new class of designs called Network Balanced Designs Type II (NetBD2) is proposed for use in such experimental situations.

Network Balanced Design (NetBD): NetBD refers to a circular design based on the network model in which each tree species on a plot has every other tree species appearing as left, right, top and bottom neighbours equal (constant) number of times. Here, balance indicates combinatorial balance only.

Experimental setup and model: The linear network effects model of Parker et al. (2017) can be considered, which should effectively account for main and nondirectional interference effects of trees in an agroforestry trial as stated by Birteeb (2021).

Consider an agroforestry experiment where same crop but (v) different tree species are planted on n plots, each plot has only one tree species. Assuming that the response Y_i (measured from the crop) is a result of "tree effect" ($\tau_{j,i}$) from plot i having tree species j, and "tree network effect" ($\delta_{l,k}$) if tree species l is planted on an adjacent connected plot k. Each of the n plots is connected by 4 other plots surrounding it. Let $\boldsymbol{A}_{n\times n}$ is a symmetric adjacency matrix for this experiment, and let $\boldsymbol{u}_j$ be the indicator vector with j^{th} element equal to 1 when tree species j is planted on plot i and 0 otherwise, then the network effects model is expressed in matrix notation as:

$$\boldsymbol{Y} = \mu\boldsymbol{1} + \boldsymbol{U\tau} + \boldsymbol{AU\delta} + \boldsymbol{\varepsilon}$$

where, $\boldsymbol{Y}$ is $n \times 1$ vector of observations, μ is grand mean, $\boldsymbol{1}$ is a $n \times 1$ vector of unities, $\boldsymbol{U}$ is a $n \times v$ design matrix of observations versus direct tree species, $\boldsymbol{\tau}$ is a $v \times 1$ vector of direct tree effects, $\boldsymbol{N} = \boldsymbol{AU}$ is a $n \times v$ design matrix of observations versus all adjacent treatments, $\boldsymbol{\delta}$ is a $v \times 1$ vector of all network effects, $\boldsymbol{X}$ is a $n \times (2v + 1)$ design matrix, $\boldsymbol{\theta}$ is a $(2v + 1) \times 1$ vector of parameters, $\boldsymbol{\varepsilon}$ is a $n \times 1$ vector of errors, with $E(\boldsymbol{\varepsilon}) = \boldsymbol{0}$ and $D(\boldsymbol{\varepsilon}) = \sigma^2\boldsymbol{I}_n$.

Example: Let there be $v = 7$ tree species. Then the number of arrays required is $\frac{v-1}{2} = 3$. The initial arrays (for $g = 1, 2, 3$) are developed as:

Array I						
0	1	2	3	4	5	6
1	2	3	4	5	6	0
2	3	4	5	6	0	1
3	4	5	6	0	1	2
4	5	6	0	1	2	3
5	6	0	1	2	3	4
6	0	1	2	3	4	5

Array II						
0	2	4	6	1	3	5
2	4	6	1	3	5	0
4	6	1	3	5	0	2
6	1	3	5	0	2	4
1	3	5	0	2	4	6
3	5	0	2	4	6	1
5	0	2	4	6	1	3

Array III						
0	3	6	2	5	1	4
3	6	2	5	1	4	0
6	2	5	1	4	0	3
2	5	1	4	0	3	6
5	1	4	0	3	6	2
1	4	0	3	6	2	5
4	0	3	6	2	5	1

After adding 1 to every element and making each array circular, the final NetBD2 is:

	7	1	2	3	4	5	6	
5	1	2	3	4	5	6	7	1
1	2	3	4	5	6	7	1	2
2	3	4	5	6	7	1	2	3
3	4	5	6	7	1	2	3	4
4	5	6	7	1	2	3	4	5
5	6	7	1	2	3	4	5	6
6	7	1	2	3	4	5	6	7
	1	2	3	4	5	6	7	

	6	1	3	5	7	2	4	
6	1	3	5	7	2	4	6	1
1	3	5	7	2	4	6	1	3
3	5	7	2	4	6	1	3	5
5	7	2	4	6	1	3	5	7
7	2	4	6	1	3	5	7	2
2	4	6	1	3	5	7	2	4
4	6	1	3	5	7	2	4	6
	1	3	5	7	2	4	6	

	5	1	4	7	3	6	2	
5	1	4	7	3	6	2	5	1
1	4	7	3	6	2	5	1	4
4	7	3	6	2	5	1	4	7
7	3	6	2	5	1	4	7	3
3	6	2	5	1	4	7	3	6
6	2	5	1	4	7	3	6	2
2	5	1	4	7	3	6	2	5
	1	4	7	3	6	2	5	

The layout of the design can be obtained as generated using the developed SAS macro by just entering the number of lines.

```
/*Developed by- Peter T. Birteeb, Eldho Varghese, Cini Varghese, Seema Jaggi and Mohd Harun*/
/*Date: 10-07-2022*/
/*VERSION 1.0: 10-07-2022*/
/*It provides generation of Network Balanced Designs Type II (NetBD2) */
OPTIONS NODATE NOSTIMER LS=78 PS=60;
%let v=7; /*Enter the number of treaments (v must be prime number) */
ods rtf file="NETWORK BALANCED DESIGN.rtf";
title 'NETWORK BALANCED DESIGN';
```

```
proc iml;
pp1=1;
do i=2 to &v-1;
pp=mod(&v,i);
if pp=0 then pp1=0;
end;
if pp1=0 then do;
print 'Entered number is not a prime number';
end;
if pp1^=0 then do;
print "NETWORK BALANCED DESIGN for v = &v";
Square=j(&v,&v,0);
do i=1 to &v;
do j=1 to &v;
Square[i,j]=mod((i-1)+(j-1),&v)+1;
end;
end;
do k=1 to (&v-1)/2;
if k=1 then do;
NBD1=Square;
end;
else do;
do i=1 to nrow(square);
do j=1 to ncol(square);
NBD1[i,j]=mod(Square[i,j]+(j-1)+(i-1),&v);
if NBD1[i,j]=0 then NBD1[i,j]=&v;
end;
end;
end;
Square=NBD1;
a0=j(1,1,'Border_Plots');
a1_l=NBD1[ ,ncol(NBD1)];
a2_l=char(a1_l,4,0);
*a3_l=a0//a2_l//a0;
a1_r=NBD1[ ,1];
a2_r=char(a1_r,4,0);
*a3_r=a0//a2_r//a0;
a1_t=NBD1[nrow(NBD1), ];
a2_t=char(a1_t,4,0);
a3_t=a0||a2_t||a0;
a1_b=NBD1[1, ];
a2_b=char(a1_b,4,0);
a3_b=a0||a2_b||a0;
a4=char(NBD1,4,0);
NBD=a3_t//(a2_l||a4||a2_r)//a3_b;
print 'Square Number=' K;
print NBD;
```

```
print 'Note: Circular border plots has been considered for all the four sides viz., left, right, top and bottom';
end;
end;
run;
ods rtf close;
quit;
```

SAS Output

NETWORK BALANCED DESIGN

NETWORK BALANCED DESIGN for v = 7

	k
Square Number=	1

NBD									
	COL1	COL2	COL3	COL4	COL5	COL6	COL7	COL8	COL9
ROW1	Border_Plots	7	1	2	3	4	5	6	Border_Plots
ROW2	7	1	2	3	4	5	6	7	1
ROW3	1	2	3	4	5	6	7	1	2
ROW4	2	3	4	5	6	7	1	2	3
ROW5	3	4	5	6	7	1	2	3	4
ROW6	4	5	6	7	1	2	3	4	5
ROW7	5	6	7	1	2	3	4	5	6
ROW8	6	7	1	2	3	4	5	6	7
ROW9	Border_Plots	1	2	3	4	5	6	7	Border_Plots

Note: Circular border plots has been considered for all the four sides viz., left, right, top and bottom

	k
Square Number=	2

NBD									
	COL1	COL2	COL3	COL4	COL5	COL6	COL7	COL8	COL9
ROW1	Border_Plots	6	1	3	5	7	2	4	Border_Plots
ROW2	6	1	3	5	7	2	4	6	1
ROW3	1	3	5	7	2	4	6	1	3
ROW4	3	5	7	2	4	6	1	3	5
ROW5	5	7	2	4	6	1	3	5	7
ROW6	7	2	4	6	1	3	5	7	2
ROW7	2	4	6	1	3	5	7	2	4
ROW8	4	6	1	3	5	7	2	4	6
ROW9	Border_Plots	1	3	5	7	2	4	6	Border_Plots

Note: Circular border plots has been considered for all the four sides viz., left, right, top and bottom

	k
Square Number=	3

NBD									
	COL1	COL2	COL3	COL4	COL5	COL6	COL7	COL8	COL9
ROW1	Border_Plots	5	1	4	7	3	6	2	Border_Plots
ROW2	5	1	4	7	3	6	2	5	1
ROW3	1	4	7	3	6	2	5	1	4
ROW4	4	7	3	6	2	5	1	4	7
ROW5	7	3	6	2	5	1	4	7	3
ROW6	3	6	2	5	1	4	7	3	6
ROW7	6	2	5	1	4	7	3	6	2
ROW8	2	5	1	4	7	3	6	2	5
ROW9	Border_Plots	1	4	7	3	6	2	5	Border_Plots

Note: Circular border plots has been considered for all the four sides viz., left, right, top and bottom

References

Birteeb, P. T. (2021). Designing agroforestry systems for sustainable livelihood. Unpublished Ph.D. Thesis, ICAR-Indian Agricultural Research Institute, New Delhi.

Parker, B. M., Gilmour, S. G., Schormans, J. (2017). Optimal design of experiments on connected units with application to social networks. *Journal of the Royal Statistical Society, Series C*, **66**(3), 455–480.