SAS macro to generate Network Balanced Designs Type I (NetBD1) involving multiple trees and monocrop agroforestry systems

Developed By

Peter T. Birteeb[1], Eldho Varghese[2], Cini Varghese[1], Seema Jaggi[3] and Mohd Harun[1]

[1]Division of Design of Experiments, CAR-Indian Agricultural Statistics Research Institute
[2]Fisheries Resources Assessment & Economics Division, ICAR-Central Marine Fisheries Research Institute
[3]Human Resource Development, Krishi Anusandhan Bhavan II, ICAR, New Delhi

Email: bpetert2000@gmail.com; eldho.varghese@icar.gov.in; cini.varghese@icar.gov.in; seema.jaggi@icar.gov.in; mohd.harun@icar.gov.in

Network Balanced Design (NetBD): NetBD refers to a design based on the network effects model in which each treatment has every other treatment appearing as left, right, top and bottom neighbours equal (constant) number of times. By this definition, a NetBD is combinatorially balanced and circular, thus having all the treatments in the first row (column) as borders to the last row (column) and vice versa. In the context of agroforestry with the aim to estimate effects of trees, each tree species will have other tree species planted in all adjacent plots equal number of times. Therefore, 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 trail as stated by Birteeb et al. (2020) and Birteeb (2021).

Experimental setup and model: 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, then the network effects model is given as:

$$Y_i = \mu + \tau_{j,i} + \sum_{k=1}^{n} A_{ik}\delta_{l,k} + \varepsilon_i$$

$$i = 1,2,\dots,n;\ k = 1,2,\dots,n;\ i \neq k;\ j = 1,2,\dots,v;\ l = 1,2,\dots,v;$$

where μ is general mean and ε_i are assumed to be identically, independently and normally distributed with 0 mean and constant variance, σ^2.

Example: Let $v = 5$ tree species. The 4 initial columns are:

Col. 1	Col. 2	Col. 3	Col. 4
0	0	0	0
1	2	3	4
2	4	1	3
3	1	4	2
4	3	2	1

After developing each initial column cyclically mod 5 and adding 1 to every element, the 4 square arrays of size 5 each is given as:

Array I					Array II					Array III					Array IV				
1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
2	3	4	5	1	3	4	5	1	2	4	5	1	2	3	5	1	2	3	4
3	4	5	1	2	5	1	2	3	4	2	3	4	5	1	4	5	1	2	3
4	5	1	2	3	2	3	4	5	1	5	1	2	3	4	3	4	5	1	2
5	1	2	3	4	4	5	1	2	3	3	4	5	1	2	2	3	4	5	1

Arranging corresponding columns together results in formation of 5 arrays each of size 5×4, and upon making the design circular, the final NetBD1 for 5 tree species is obtained below.

	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	
5	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	1
4	2	3	4	5	3	4	5	1	4	5	1	2	5	1	2	3	1	2	3	4	2
3	3	5	2	4	4	1	3	5	5	2	4	1	1	3	5	2	2	4	1	3	3
2	4	2	5	3	5	3	1	4	1	4	2	5	2	5	3	1	3	1	4	2	4
1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5
	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	

The layout of the design can be obtained using the program written in SAS IML in the form of a Macro by just entering the number of treatments.

```
/*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 I (NetBD1) */

OPTIONS NODATE NOSTIMER LS=78 PS=60;
%let v=5; /*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;
first=j(1,&v-1,&v);
```

```
Square=j(&v-1,&v-1,0);
do i=1 to &v-1;
do j=1 to &v-1;
Square[i,j]=mod(i*j,&v);
end;
end;
square=first//square;
*print square;
NBD1=j(&v,(&v-1)*&v,0);
do k=1 to &v;
do i=1 to &v;
do j=1 to &v-1;
NBD1[i,(&v-1)*(k-1)+j]=mod(Square[i,j]+(k-1)+1,&v);
if NBD1[i,(&v-1)*(k-1)+j]=0 then NBD1[i,(&v-1)*(k-1)+j]=&v;
end;
end;
end;
print "NETWORK BALANCED DESIGN for v = &v";
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 NBD;
print 'Note: Circular border plots has been considered for all the four sides viz., left, right, top
and bottom';
end;
run;
ods rtf close;
quit;
```

<u>SAS OUTPUT</u>

The SAS System

NETWORK BALANCED DESIGN for v = 5

NBD																						
	COL1	COL2	COL3	COL4	COL5	COL6	COL7	COL8	COL9	COL10	COL11	COL12	COL13	COL14	COL15	COL16	COL17	COL18	COL19	COL20	COL21	COL22
ROW1	Border_Plots	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	Border_Plots
ROW2	5	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	1
ROW3	4	2	3	4	5	3	4	5	1	4	5	1	2	5	1	2	3	1	2	3	4	2
ROW4	3	3	5	2	4	4	1	3	5	5	2	4	1	1	3	5	2	2	4	1	3	3
ROW5	2	4	2	5	3	5	3	1	4	1	4	2	5	2	5	3	1	3	1	4	2	4
ROW6	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5
ROW7	Border_Plots	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	Border_Plots

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

<u>References</u>

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

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