OPTIMAL NEIGHBOR BALANCED DESIGNS TO IMPROVE AGRICULTUAL ECONOMY

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ABSTRACT

Agricultural growth plays a vital role in improving Pakistan's economy. Agriculture sector of Pakistan is considered as a major productive sector of Pakistan's economy. Around 61% population is living in more than 50,000 villages in Pakistan. Economic development, progress and prosperity cannot be achieved without improving agricultural sector. It provides employment opportunities and produces exportable items for foreign exchange. So, agricultural sector is helpful to make rapid economic development. Neighbor designs increase the production and improve efficiency in agriculture, horticulture and forestry by minimizing the experimental error. In agriculture, guiding principle of neighbor design is to enhance production through effectiveness of cost and time by minimizing neighboring treatment/plot effect which contributes significantly to GDP growth and leads to poverty reduction. Neighbor effects in agriculture can be observed in experiments where tall plants effect the growth and production of neighboring smaller plants. Neighbor designs reduce this neighbor effect. In this paper optimal neighbor balanced designs are developed which increase the agricultural economy. A series of optimal one-dimensional neighbor designs have been developed for odd prime number of treatments.

Keywords: Agricultural economic models; Optimal criteria; Neighbor designs; Primitive roots

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1. Introduction

Economic development and prosperity cannot be achieved without strong agricultural sector. It provides employment opportunities to a lot of people. It produces exportable items, which increases the foreign exchange resources. So, agricultural sector is helpful to make rapid economic development. Agricultural growth plays the key role in poverty reduction. Agricultural crop production is the most important source for a majority of rural households to improve their economy. So there is need to develop neighbor agricultural economic designs which can increase the agricultural production for enhancing the economy of Pakistan. Neighbor designs reduce experimental error in agricultural fields and applicable in situations where different crops (treatments) effect their neighboring crops. Neighbor effects can be caused by differences in height, root vigor, or germination date of plant. Similarly fertilizer, irrigation, or pesticide applied on one plot may cause neighbor effect to its adjacent plots. The aim of this research paper is to develop neighbor designs which decrease neighbor effect so that production should be increased. Neighbor designs on one dimension are used in in block design setup in the field of agriculture with bordered plots. These bordered plots are situated on each end of block in order to make the circular design. Agriculture on mountains where crops are cultivated on natural circular blocks is an example of one-dimensional neighbor circular design. Each cultivated plot is nearest neighbor to the next and hence along with the effect of its own it may yield the effects of its neighboring plots. Rees (1967) introduced one-dimensional neighbor balanced designs for the ouchterlony gel diffusion test. Then several researcher worked on it see for example Misra *et al.,* (1991), Chaure and Misra (1996), Druilhet (1999), Bailey and Druihet (2004), Mingyao *et al.,* (2007), Nutan (2007), Hamad *et al.,* (2010), Ahmed and Akhtar (2011), Hamad and Hanif (2011).

2. Agricultural Economic Models of Neighbor Designs

In Pakistan, almost all our economic activities are based on agriculture sector. Agriculture has direct and indirect impact on economic growth. This not only provides food to consumers but also is a source of scarce foreign exchange earnings. It provides a market for industrial goods. It is explained by different researchers that when blocks are binary and circular then agricultural economic neighbor balanced designs are optimal for neighbor effects. These designs are very useful for increasing agricultural economy of Pakistan. Druilhet (1999) proved that a design which is circular, binary, equi-replicated, pair wise balanced and equi-neighbor balanced is universally optimal. Universal optimality given by Keifer (1975) is a strong family of optimality criteria which includes A-optimality, D-optimality and E-optimality criteria as particular cases. This criterion requires maximum trace and complete symmetry from the information matrix of a design. One can see Druilhet (1999), Bailey and Druihet, (2004) and Mingyao *et al.*, (2007) for the universal optimality of one-dimensional neighbor balanced circular designs. Our constructed series generate neighbor balanced designs that meet the universal optimality criterion and conditions given in those research papers (Hamad and Hanif, 2011). The developed designs are optimal universally for the agricultural economic models of neighbor effects given below;

$$Y_{ij} = \mu + \tau_{(i,j)} + \beta_j + \varphi_{(i-1,j)} + \varepsilon_{ij} \qquad (1)$$

$$Y_{ij} = \mu + \tau_{(i,j)} + \beta_j + \varphi_{(i-1,j)} + \varphi_{(i+1,j)} + \varepsilon_{ij} \qquad (2)$$

"Y_{ij} is the production from the *i*th plot in the *j*th block, μ is overall mean, $\tau_{(i,j)}$ is direct effect of the treatment in the *i*th plot of *j*th block, β_j is the effect of the *j*th block, $\varphi_{(i-1,j)}$ is the left neighbor effect due to the treatment in the (*i*-1)th plot of *j*th block, $\{\varphi_{(i-1,j)}, \varphi_{(i+1,j)}\}$ is the un-differentiated neighbor effect due to the treatment in (*i*-1)th plot and (*i*+1)th plot of *j*th block, i.e., neighbor effect due to left treatment is same to the neighbor effect of right treatment and ε_{ij} is error assumed to be independent and normal (Hamad and Hanif, 2011).

3. Optimal Agricultural Economic Neighbor Balanced Designs

Neighbor balanced designs are those designs in which each pair of distinct neighboring treatment appear equally and blocks are circular. Smallest primitive root *p* of odd prime number *m* has been used in the construction of designs. A binary series of neighbor balanced designs for odd prime number of treatments is generated through smallest primitive root, when each treatment has every other treatment as neighbor exactly once to its left and exactly once to its right. No series of binary neighbor balanced circular design for odd prime number of treatments is ever developed in literature for which each treatment has remaining treatments as neighbor exactly once to its left and exactly once to its right (Hamad and Hanif, 2011).

3.1 Theorem 1

Let $v = m$ treatments are taken where m is odd prime number with p is primitive root of odd prime number. The first block of following treatments is given as $\mathbf{I} = \left\{ 1, p^{m-2}, p^{m-3}, \ldots, p \right\}$. This first block generates a series of binary neighbor balanced circular design with parameters $k = r = m$-1, $b = v$, $\lambda = 2$, when developed under mod (v). In this design every treatment occur as neighbor exactly once to the left and exactly once to the right for any fixed treatment θ.

Proof: Let the $k = (m$-1) distinct treatments appearing in first circular block $\mathbf{I} = \left\{ 1, p^{m-2}, p^{m-3}, \ldots, p \right\}$ under modulo v. "From the initial block the forward and backward differences are; $\pm(p^{m-2}-1) \pm (p^{m-3}-p^{m-2}), \pm(p^{m-4}-p^{m-3}), \ldots\ldots\ldots, \pm(1-p)$. The remaining blocks are derived from the initial block by cycling the treatment. Among the totality of forward and backward differences all differences appears twice giving $\lambda = 2$. In each forward and backward difference of all blocks there exists positive difference for each negative difference and it shows that for any fixed treatment θ, all other treatments occur as neighbor once as left and once as right neighbor. The above initial block develops a series of binary neighbor balanced circular designs with parameters $k = r = m$-1, $b = v$, $\lambda = 2$.

Corollary 3.1: Designs developed through theorem 1 are balanced incomplete block designs (BIBD). These designs fulfill following requirements of BIBD;

(1) $bk = rv = N$;
(2) $r(k\text{-}1) = \lambda\ (v - 1)$, ($\lambda$ in BIBD is quite different from λ of neighbor design);
(3) $b = v$.

When design is neighbor balanced and pair wise balanced then all treatment differences are estimated with equal precision (Hamad and Hanif, 2011).

Example 3.1

Let $v = m = 17$, $p = 3$. The binary initial block of size 16 is;

I = (1, 6, 2, 12, 4, 7, 8, 14, 16, 11, 15, 5, 13, 10, 9, 3).

Forward and backward differences of initial block are;

$$= \pm(5), \pm(-4), \pm(10), \pm(-8), \pm(3), \pm(1), \pm(6), \pm(2) \pm(-5), \pm(4), \pm(-10), \pm(8), \pm(-3), \pm(-1), \pm(-6), \pm(-2).$$

Each difference is repeated twice, irrespective of mathematical signs, which shows that each treatment would occur as neighbor with every treatment equally. In backward and forward differences, there is positive difference for each negative difference which shows that for fixed treatment θ, the rest treatments occur as neighbor once to the left and once to the right giving $\lambda = 2$. Sum of all these differences is equal to zero. The remaining binary blocks can be obtained cyclically under modulo 17 through initial block as;

(2, 7, 3, 13, 5, 8, 9, 15, 0, 12, 16, 6, 14, 11, 10, 4), (3, 8, 4, 14, 6, 9, 10, 16, 1, 13, 0, 7, 15, 12, 11, 5), (4, 9, 5, 15, 7, 10, 11, 0, 2, 14, 1, 8, 16, 13, 12, 6), (6, 11, 7, 0, 9, 12, 13, 2, 4, 16, 3, 10, 1, 15, 14, 8), (7, 12, 8, 1, 10, 13, 14, 3, 5, 0, 4, 11, 2, 16, 15, 9), (5, 10, 6, 16, 8, 11, 12, 1, 3, 15, 2, 9, 0, 14, 13, 7), (8, 13, 9, 2, 11, 14, 15, 4, 6, 1, 5, 12, 3, 0, 16, 10), (9, 14, 10, 3, 12, 15, 16, 5, 7, 2, 6, 13, 4, 1, 0, 11), (10, 15, 11, 4, 13, 16, 0, 6, 8, 3, 7, 14, 5, 2, 1, 12), (11, 16, 12, 5, 14, 0, 1, 7, 9, 4, 8, 15, 6, 3, 2, 13), (13, 1, 14, 7, 16, 2, 3, 9, 11, 6, 10, 0, 8, 5, 4, 15), (12, 0, 13, 6, 15, 1, 2, 8, 10, 5, 9, 16, 7, 4, 3, 14), (14, 2, 15, 8, 0, 3, 4, 10, 12, 7, 11, 1, 9, 6, 5, 16), (15, 3, 16, 9, 1, 4, 5, 11, 13, 8, 12, 2, 10, 7, 6, 0), (16, 4, 0, 10, 2, 5, 6, 12, 14, 9, 13, 3, 11, 8, 7, 1), (0, 5, 1, 11, 3, 6, 7, 13, 15, 10, 14, 4, 12, 9, 8, 2).

These blocks yield a binary neighbor balanced circular design with parameters: $b = v = 17$, $r = k = 16$ and $\lambda = 2$. The above design is balanced incomplete block design with $\lambda = 15$. (Hamad and Hanif, 2011).

Note: Catalogue of above theorem 1 is given for $v = 43$. For $v > 43$, neighbor designs can be generated by the theorem.

Table 1 (Theorem 3.1)
Binary Neighbor balanced Circular Designs for $v = m$ and $\lambda = 2$

m	p	Initial block
5	2	(1, 3, 4, 2)
7	3	(1, 5, 4, 6, 2, 3)
11	2	(1, 6, 3, 7, 9, 10, 5, 8, 4, 2)
13	2	(1, 7, 10, 5, 9, 11, 12, 6, 3, 8, 4, 2)
17	3	(1, 6, 2, 12, 4, 7, 8, 14, 16, 11, 15, 5, 13, 10, 9, 3)
19	2	(1, 10, 5, 12, 6, 3, 11, 15, 17, 18, 9, 14, 7, 13. 16, 8, 4, 2)
23	5	(1, 14, 12, 7, 6, 15, 3, 19, 13, 21, 18, 22, 9, 11, 16, 17, 8, 20, 4, 10, 2, 5)
29	2	(1, 15, 22, 11, 20, 10, 5, 17, 23, 26, 13, 21, 25, 27, 28, 14, 7, 18, 9, 19, 24, 12, 6, 3, 16, 8, 4, 2)
31	3	(1, 21, 7, 23, 18, 6, 2, 11, 14, 15, 5, 12, 4, 22, 28, 30, 10, 24, 8, 13, 25, 29, 20, 17, 16, 26, 19, 27, 9, 3)
37	2	(1, 19, 28, 14, 7, 22, 11, 24, 12, 6, 3, 20, 10, 5, 21, 29, 33, 35, 36, 18, 9, 23, 30, 15, 26, 13, 25, 31, 34, 17, 27, 32, 16, 8, 4, 2)
41	6	(1, 7, 8, 15, 23, 38, 20, 17, 37, 13, 9, 22, 31, 12, 2, 14, 16, 30, 5, 35, 40, 34, 33, 26, 18, 3, 21, 24, 4, 28, 32, 19, 10, 29, 39, 27, 25, 11, 36, 6)
43	3	(1, 29, 24, 8, 17, 20, 21, 7, 31, 39, 13, 33, 11, 18, 6, 2, 15, 5, 16, 34, 40, 42, 14, 19, 35, 26, 23, 22, 36, 12, 4, 30, 10, 32, 25, 37, 41, 28, 38, 27, 9, 3)

4. Discussion

Agriculture is accounted for almost 50% of economic output in Pakistan. In agriculture, confusion arises over the different causes of neighbor effect between neighboring treatments and specification of appropriate models. An expert has to select very carefully an appropriate economic model according to the causes of neighbor effects. If it is not selected carefully then it is not possible to predict results. Neighbor effects, either due to layout of plots or natural, can deprive the results from its representative-ness. Neighbor designs of one dimension are important tools to control it. Neighbor designs for $4n$+3 (power of prime) treatments and $4n$-1 (power of prime) treatments exist in literature but no attention has been given for the construction of all odd prime numbers using primitive roots. Agricultural economic optimal neighbor balanced deigns are developed for odd prime number of treatments to increase the agricultural economy. The optimality is under assumption that all treatments are uncorrelated and have common variance.

5. Conclusion

A major part of the Pakistan's economy depends on production of agricultural commodities which in turn results an increase in national as well as individual's income. Around 45.0% of our labour force and 66.7% of our rural population is directly involved in agriculture sector. If productivity increases in agriculture it reduces poverty and improves the economy. So, growth of agricultural sector will cause to improve the standard of living of the population. In this paper optimal agricultural economic neighbor balanced designs are developed which can increase the agricultural economy. Designs can be derived through theorem given in the paper. By applying these designs in agriculture, production can be enhanced which finally leads to strong economy.

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