THE COCONUT AS A SOLAR ENERGY COLLECTOR: PLANTING GEOMETRIES

Julian A. Banzon
Emeritus Professor
University of the Philippines Los Baños
College, Laguna, Philippines

ABSTRACT

The usual square and triangular planting geometries are given attention. The square geometry is found to utilize only 78.5% of the land area, irrespective of the planting distance ($2r$). The unoccupied space is in patches numbering $2500/r^2$ (per hectare) each with an area equal to $0.8584r^2$, and approximately square in shape. To utilize the unoccupied area (2,154 m^2/ha), planting arrangements are proposed.

Introduction

Countries without much petroleum or natural gas deposits are trying hard to locate other sources of energy. Fuels for motor vehicles are particularly difficult to locate. One of the more promising solutions to this problem is to raise forests of plants. The logic is that plants through photosynthesis, catch, collect and store solar enegy in the form of biomass. In the Philippines, we have the unique situation of having already a huge forest of coconut palms. The magnitude of this forest can be appreciated when we multiply 400 million coconut palms x 50 sq. m (which is the average ground area covered by one palm) to give us 20,000 million sq. m of leaf exposure to the sun. Compare this size to man-made silicon solar cells, where a 10 m x 10 m is already prohibitively costly. Discussed in previous papers is the amount of energy stored by our coconut plantation (Banzon, 1981). It may be noted that while solar energy lends itself rather easily to direct use, the storage of the energy (usually in storage batteries) is still far from satisfactory; this is not the case with photosynthesis.

The commercial growing of coconuts at present is meeting two problems:

1. Among established coconut groves, it is necessary to intercrop among the palms in order to improve the profitability of the groves. This is especially true in the small plantation owned areas.
2. There is a need for replanting the groves of old palms.

The following options are now available:

1) Intercrop using the areas available in established groves. We should, therefore, have knowledge of the size and shapes of these areas; this depends partly on the geometry of the planting system, of which two are in use: square and triangular. The present study explores these geometries in relation to the areas available for intercrop.
2) In planting for new groves, or in replanting old groves, no provision may be made for intercropping which means the entire area is planted to coconuts as a solar energy collector. Intercropping, if later desired, is to be done using any unused area between or among palms. The determination of the area thus available is one objective of this present study.
3) Special provision is made for intercropping areas in establishing new coconut groves or in replanting. Since we are using the coconut palm as our renewable energy source, we should plan to maximize the number of palms per unit area of land e.g. per hectare, but we should give enough area for the intercrop, for reasons stated earlier. Since we cannot anticipate what the plants for intercropping are (this will depend on what intercrops are most in demand for a particular region), one part of the present study is to explore some planting geometries which could suit the requirements of the farmer.

Traditional Planting Geometries

In setting up new coconut groves, the practice is to adopt a particular spacing (Magat, 1978): this is the distance of a circle supposed to be occupied by the palm and is equal to the diameter of a circle supposed to be occupied by the palm. There are two ways of arranging such circles: the square (□) and the triangular (Δ). See Fig. 1.

In any case, the area within the above-mentioned circle is πr^2 and the maximum number of palms in a hectare (ha) is $10{,}000/\pi r^2$.

In the □ planting geometry, the number of palms/ha is $N = (100/2r)(100/2r)$ or $10{,}000/4r^2$.

In the Δ planting geometry, the number of palms/ha is $N = (100/2r)(100/r\sqrt{3}$ or $10{,}000/2r^2\sqrt{3}$. The term $r\sqrt{3}$ is obtained from Fig. 2. These two equations form the basis for the much used table of spacing distances being used in planting coconut groves.

Note that the ratio of palms/ha in the Δ geometry, to that of the □ is $4r^2/2r^2\sqrt{3}$ or 1.15, i.e. the Δ geometry allows 15 percent more palms, regardless of the value of r.

The actual area occupied by palms in a ha is area occupied by each palm (πr^2) x no. of palms. This area is

$$\pi r^2 \times 10{,}000/4r^2 = 7{,}854 \text{ m}^2 \text{ for □ geometry}$$

$$\pi r^2 \times 10{,}000/2r^2\sqrt{3} = 9{,}069 \text{ m}^2 \text{ for } \Delta \text{ geometry}$$

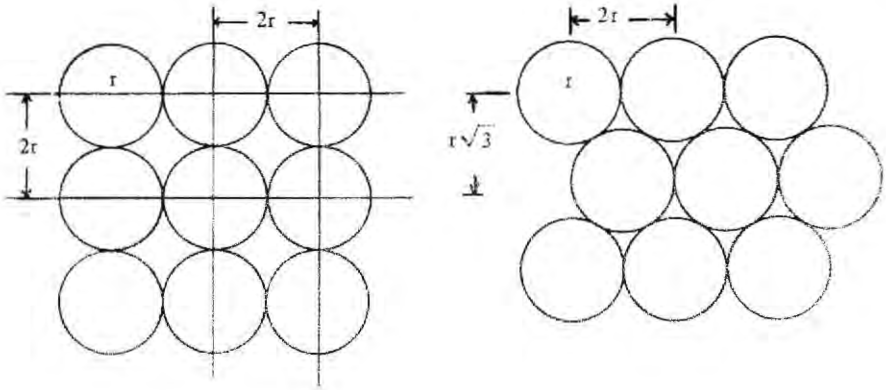
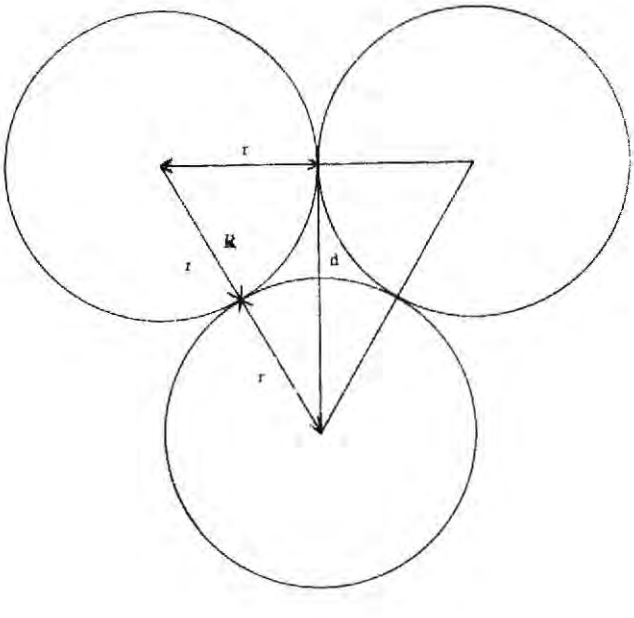


Fig. 1. Traditional Planting Geometries.



$$d = \sqrt{(2r)^2 - r^2} = r\sqrt{3} = 1.732r$$

Fig. 2. Triangular Planting Geometry.

Note that a) these occupied areas are independent of r.

b) the Δ geometry is more "efficient" using over 90% of the land for palms.

c) the □ geometry, while less efficient for palm cultivated, offers 2,146 m^2/ha for an "intercrop".

The shape and size of the unoccupied space (we will call the "crop" area "A") can be deduced from Fig. 3a. The area "A" is equal to the area of the square *a b c d* minus the sum of the 4 sectors (shaded). Hence,

$$\text{"A"} = (2r)^2 - 4\left(\frac{90^\circ}{360^\circ} \times \pi r^2\right) = 4r^2 - \pi r^2 = .8584r^2 \text{ sq.m}$$

This is for □ geometry. The value of "A" for Δ geometry is (Fig. 3b):

$$\text{"A"} = 2 \quad \frac{1}{2} \quad r \times r\sqrt{3} - \left(\frac{60^\circ}{360^\circ} \pi r^2\right)3$$

$$= r^2\sqrt{3} - \pi r^2/2$$

$$= 0.1612r^2$$

In actual practice, r varies from 2 to 5 meters. These equations for "A" show that the □ geometry offers larger areas for intercropping than the Δ arrangement.

The "A" areas are unconnected and knowledge of their number/ha may be of value. This number may be calculated by dividing the unused area (2,146 m^2 for □) by the value of one "A" which is $0.8584r^2$, giving $2500/r^2$ per ha in the □ geometry and $5775/r^2$ per ha in the Δ geometry. Some of the characteristics of these unoccupied areas (the "A" areas) are given in Table 1. A summary of information comparing the square and the triangular systems of spacing is given in Table 2.

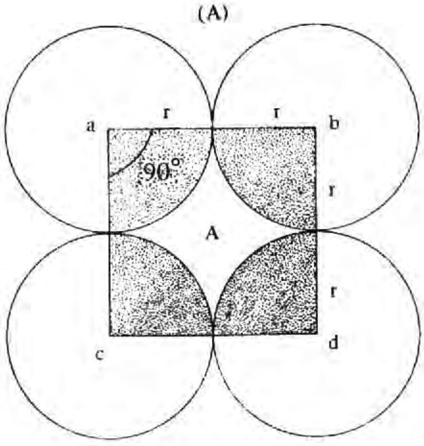
The discussion on the square planting system has brought out the following:

a) An area of 2,146 m^2/ha is unused in coconut groves.

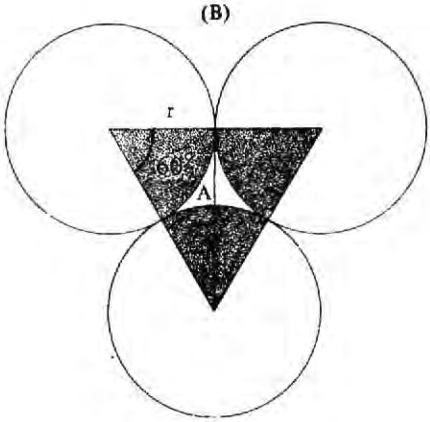
b) This unused area is distributed in patches among the palms.

c) Each patch varies in area from 10.5 m^2 to 21.5 m^2 depending on the value of r.

d) There are as many of these patches as there are palms/ha.



$$A = (2r)^2 - \pi r^2$$
$$= 0.8584r^2$$



$$A = (r \times r\sqrt{3}) - 3\ \frac{\pi r^2}{6}$$
$$= 0.1612r^2$$

Fig. 3a. Vacant area in the square planting geometry.

Fig. 3b. Vacant area in the triangular planting geometry.

Table 1. Characteristics of unoccupied areas ("A" areas)

	Square		*Triangular*	
$r_1 m$	*no. of units/ha*	*area/unit, m^2*	*no. units*	*area/units*
5.0	100	21.46	228	4.04
4.5	123	17.45	282	3.26
4.0	156	13.75	357	2.58
3.5	204	10.50	466	1.97

Table 2. Summary information on the square and triangular geometries of coconut planting

1. Geometry	Square	Triangular
2. Distance between rows, m	$2r$	$r\sqrt{3}$
3. No. of palms/ha	$2500/r^2$	$2890/r^2$
4. Area/palms, m^2	πr^2	πr^2
5. Area, all palms/ha, m^2	7854	9079
6. Area unoccupied, m^2	2146	921
7. Area/unit unoccupied, m^2	$0.8584r^2$	$0.1612r^2$
8. No. unoccupied units	$2500/r^2$	$5713/r^2$
9. Approx. shape of unit	square	triangular

Utilization of the Unused Areas in Coconut Groves

The simplest way to accomplish this is to plant an intercrop; the unused areas are rather large (10.5 m^2 to 21.5 m^2) and can accommodate even large trees, such as coffee and cacao. Intercropping is now being practiced. In a 10 m-spaced grove of coconuts, there are 100 units of these unoccupied areas, each of 21.5 m^2.

Instead of patches of land for cropping, it may be more convenient to have available a continuous strip. In a 100 m x 100 m land, the number of palms arranged in the square geometry is:

$$N = \frac{100}{2r} \times \frac{100}{2r}$$

Since the triangular geometry allows more palms than the square geometry for the same area of land, this N may be compressed into a 100 m x 78.54 m lot at a sacrifice in the size of *r*. Let this be *r*,' then:

$$\frac{100}{2r} \times \frac{100}{2r} = \frac{100}{2r^1} \times \frac{78.54}{r^1\sqrt{3}}$$

which leads to $r^1 = 0.95$

The same objective of obtaining a separate area of non-coconut crops may be achieved by retaining the normal sizes of *r* but changing the size of the palm area from 100 m x 78.54 m to 100 m x w meters. Then the equation becomes:

$$\frac{100}{2r} \times \frac{100}{2r} \times \frac{100}{2r} \times \frac{w}{r\sqrt{3}}$$

and w = 86.6

This means that the palm area is 100 m x 86.6 m while the non-crop area is 100 m x 13.4m. The number of palm would be the same as normally planted in a hectare.

Another planting geometry that appears to have many good features consists of strips of double-row palms separated by adequate widths of crop strips. The general idea may be obtained from Fig. 4. Zuñiga (1971) of the Bureau of Plant Industry, proposed one such scheme and is reported to have actually carried it in practice. Because his planting distance is rather small (4.34 m). I have re-worked the arithmetic, for larger *r* values and am presenting a summary in Table 3.

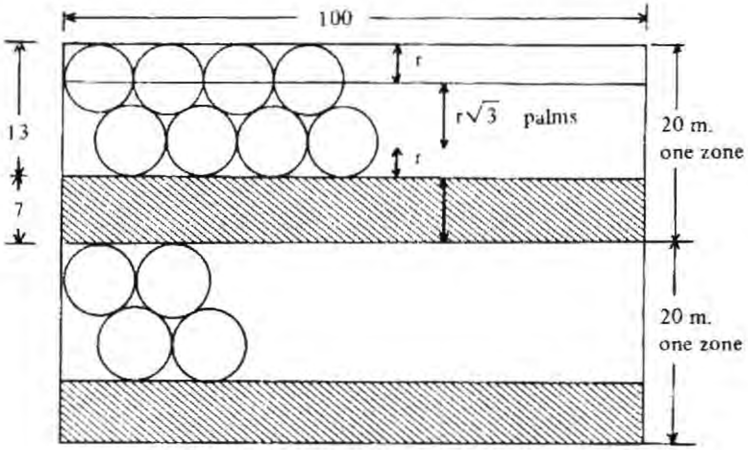


Fig. 4. Double row palms in 5 zones/Ha.

Table 3. Planting schemes for coconut palms, using alternate strips of palms and other crop plants (all values in meters)

A. value of $2r$	5	6	7
B. width, 2-palm row ($2r + r\sqrt{3}$)	9.3	11.2	13
C. no. of palms/2 rows ($(100/2r) \times 2$)	40	33	28
D. no. palm-crop strips (assumed)	6	6	5
E. width, palm-crop strip (100/no. strips)	16.7	16.7	20
F. width crop strip (E – B)	7.36	5.5	7
G. No. palms/ha (C X D)	240	198	140
H. theory, palms/ha	400	278	204
I. G/H, %	60	71	68

Summary

1. If the coconut palm is to be used as the sole solar energy collector, the triangular geometry of planting is indicated since over 90% of the land area is utilized.

2. If intercropping is desired, the use of the unutilized areas in-between the palms, the square geometry of planting is advantageous. This unutilized area (2,146 m^2 per hectare) is in unconnected units ranging in area from 10 m^2 to 21 m^2, depending on the distance of spacing.

3. If a separate area for a non-coconut crop is desired, the 7,854 m^2 ordinarily required per ha, in the square geometry, may be planted in the triangular geometry and the remaining 2,146 m^2 used wholly for the other crops. In this manner, the loss of number of palms is only about 10%, while a large single area becomes available for other crops.

Literature Cited

Banzon, Julian A. 1981. The coconut as a renewable energy source. *Trans. Nat. Acad. Sci. & Tech. (Phils.)* 3: 11-20.

Magat, Severino, S. 1978. Proper planting systems of coconuts. *Coconut Farmers Bulletin.* (Philippine Coconut Authority) 2(6): 1-5.

Zuñiga, Lorenzo. 1971. New double row system for coconut planting. Weekly Bulletin, United Coconut Association of the Philippines.