Biomass generation of the hedgerow and open fallow systems and their implication to length of the fallow period

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Abstract. This study shows that the hedgerow fallow system has the potential in reducing the fallow period as it generates massive amount of biomass in a shorter period of time. In the humid tropics, biomass plays an indispensable role in potentially supplying the nutrients needed for crop production in shifting cultivation systems. During fallow period, much of the nutrients are locked up in the biomass to prevent nutrient losses; these nutrients are then released during cropping. The massive amount of biomass generated will proportionately store up a higher amount of nutrients needed during the cropping phase. The shortening of the fallow period is most important when land availability is scare.

1. Introduction

In shifting cultivation systems, where no external fertilizer is applied, biomass production is the key in restoring soil fertility. This is especially very important in humid tropical conditions where nutrients are locked up in the biomass so as to prevent nutrient losses due to surface run-off and/or leaching. The nutrients will only be released when the plant vegetation biomass are cleared and then burned, or if not allowed to decompose naturally. Thus, the more biomass is produced the better, as more nutrients will be available for agricultural crops to grow and yield its economic produced. It is during the fallow phase that biomass is generated. In traditional shifting cultivation systems, once the land could no longer support crop production, which usually is only a year, the crop field is then abandoned and fallow vegetation is allowed to grow naturally. In this method, soil fertility restoration will take time about 10 to 25 years. This means the farmer needs around 10 to 25 farm plots before the fallowed plot is again slashed and burned for cultivation. In a growing population, where space for farming is getting scarcer, the amount of time to restore soil fertility is compromised. It is in that condition that some farmers and/or researchers have developed an innovative technology that reduces the fallow period without compromising soil fertility. That type of technology is called improved fallows. One example of which is the relatively famous Naalad Improved fallow system. This was developed more than a hundred years ago by the farmers from Barangay Naalad, Naga, Cebu. What they do is that they only maintain two plots one for cultivation and another for fallow in which each phase is interchangeable. They sow native variety of Ipil-ipil (Leucanae leucocephala) seeds and allow it to grow for seven (7) years after which the ipil-ipil are cleared and its poles are used to establish soil and water conservation structure as the farm plots are located in very steep slopes. The cultivated plots are planted for 7 years; hence there is a ratio of 1:1 cultivated-fallow plots. The Leucanae leucocephala are fast growing nitrogen fixing trees, thus they are able to produce huge amount of biomass [1] [2].
In this study, another improved fallow called the hedgerow fallow system will be evaluated in terms of the biomass produced and compare it with the traditional fallow which is called in this study as open fallow. It is hypothesized that the hedgerow fallow system will produce more biomass than the open fallow biomass, considering that there is a permanent standing biomass in the presence of contoured tree hedgerows and that N-fixing fast growing trees will contribute a lot in the production of biomass.

The hedgerow fallow system is an alley cropping system or the famously called SALT (Sloping Agriculture Land Technology) where N-fixing fast growing trees are planted along the contour and in time terraces are eventually formed, these trees are regularly pruned and the prunings are left on the alleys where crops are grown. These prunings will eventually decomposed and therefore provide nutrients to crops. SALT was designed to allow continuous cropping but in reality many are left fallowed for various reasons as documented by Suson et al. [3].

2. Objectives of the Study
In this study, the Hedgerow Fallow will be evaluated as a System in terms of its potential to generate more biomass by comparing it with the Open Fallow. The study specifically aims to:

1. Determine the amount of biomass produced in the above ground for each fallow system and to compare both fallow systems (Hedgerow and Open).
2. Determine the amount of biomass produced in the below ground for each fallow system and to compare both fallow systems (Hedgerow and Open).
3. Compare the total amount of biomass produced in the Hedgerow and Open Fallow System.

3. Materials and Methods
Above and below ground biomass was sampled.

3.1. Aboveground fallow biomass sampling
All plants found above the ground was collected and grouped according to species. Plants were removed closed to the ground but with the exception of the hedgerow wherein the hedgerow trees are cut 50 cm above the ground to simulate pruning of tree hedgerows. Also destructive sampling was avoided as far as the tree hedgerows are concerned.

The sampling area of the fallow biomass inside the alley was done using the species area curve [4]. The idea behind such method was that there was a minimal area by which plant species composition in a given area was fairly represented. Initial sampling size started with 1 m along (parallel) the hedgerow while the alley width served as the width which was always constant. The length of the sampling size was expanded 1 m at a time (0.5 m on either side) until such time that no additional species was added (Figure 1). Figure 2 shows the sampling area for the biomass.

![Figure 1. Species Area Curve (Pears, 1985).](image-url)
Figure 2. Aboveground Biomass Sampling in Open and Hedgerow Fallow Systems in Claveria, Misamis Oriental, Philippines (Suson, 2018).

Fresh weight of aboveground fallow biomass of each plant species was determined using a spring or round scale balance for heavier samples and triple beam balance for very light samples. Once the total fresh weight sample per species was recorded, a subsample of 1.50 kg of each plant species was weighed for determining dry matter and tissue analysis. Any plant fallow species that was less than 1.50 kg was used automatically as a subsample. The subsample is usually in 1.00 kg.

When sampling for hedgerow, the fresh weight of leaves and green stem and the woody stem and branches were weighed separately. Fresh subsamples of fallow biomass were oven dried at 80 °C.

3.2. Belowground fallow biomass sampling

This refers to all plant materials (roots and other plant parts that has been buried beneath the soil) found below the soil surface. Ideally, roots must also be classified according to species. That activity alone is a study by itself. Thus, all plant material below the ground was weighed as one. Collection of belowground biomass was on a per zone basis, the same sampling area by which the aboveground biomass was collected but with a quadrant holes size of 25 cm x 25 cm (Figure 3). Actual collections were done at soil depths of 15–30 cm. Mosquito netting was used to separate the soil from below ground plant material. The separation process was done on a running stream nearest to the site by constantly rubbing of the mosquito net by hands and feet on a flowing stream. This hastened the separation between the plant material and soil. The fresh weight of belowground biomass was weighed. Similarly as with aboveground fallow biomass, a 1.50 kg of subsample was used for dry weight and tissue sample. However, roots of the tree hedgerow were not dug up since destructive sampling of trees, as a matter of policy, are to be avoided.
3.3. Calculation of the amount of biomass (above and below ground) per hectare

The dry weight of the fresh weight of the fallow biomass was determined using the equation below:

\[ \text{ODWS} = \frac{(\text{ODWSS} \times \text{FWS})}{\text{FWSS}} \]

Where:
\begin{align*}
\text{ODWS} &= \text{Oven Dry Weight of the Sampled Fallow Biomass} \\
\text{ODWSS} &= \text{Oven Dry Weight of the Sub-Sample Fallow Biomass} \\
\text{FWS} &= \text{Fresh Weight of the Sampled Fallow Biomass} \\
\text{FWSS} &= \text{Fresh Weight of the Sub-Sample Fallow Biomass}
\end{align*}

Equation to calculate the amount of biomass (above and below ground) per hectare:

\[ \text{FBH} = \frac{\text{ODWS} \times 10,000 \text{ m}^2/\text{hectare}}{\text{SPA}} \]

Where:
\begin{align*}
\text{FBH} &= \text{Fallow Biomass per Hectare} \\
\text{ODWS} &= \text{Oven Dry Weight of the Sampled Fallow Biomass} \\
\text{SPA} &= \text{Sample Plot Area}
\end{align*}

3.4. Calculation of the Total Biomass of each Fallow System

For the calculation of the total biomass of the Open Fallow System, we simply added the aboveground fallow biomass (alley aboveground fallow biomass) and the belowground fallow biomass. The same as the Hedgerow Fallow System, we added its aboveground fallow biomass (alley aboveground fallow biomass plus hedgerow aboveground fallow biomass) and belowground fallow biomass.

4. Results and Discussion

4.1 Aboveground Biomass

The Hedgerow Fallow System has higher above ground biomass than the Open Fallow System at the average of 109,081.40 kg/ha and 12,494.98 kg/ha respectively (Table 1). Their difference is significant (Figure 4) with P-value less than alpha value of 0.05 (Appendix A).

The reason for the significant higher value of the hedgerow fallow system on the above ground biomass is due to the presence of the contour tree hedgerow biomass. The tree hedgerow biomass constitutes 89% of the total aboveground fallow biomass of the hedgerow fallow system (Figure 5) and has even significantly higher value than the total fallow biomass of the open fallow system (Figure 6).
Table 1. Amount of Aboveground Biomass (kg/ha) generated.

| FARMER COOPERATOR | HEDGEROW FALLOW SYSTEM | OPEN FALLOW SYSTEM |
|-------------------|------------------------|--------------------|
| CODILLA           | 133,217.83             | 12,122.04          |
| RENE              | 163,027.24             | 2,802.66           |
| PABLING 1         | 59,212.56              | 31,927.05          |
| PABLING 2         | 81,123.14              | 4,089.10           |
| CUIZON            | 108,826.22             | 11,534.03          |
| MEAN              | 109,081.40             | 12,494.98          |

Figure 4. Above Ground Biomass.

Figure 5. Magnitude of Aboveground Tree Hedgerow Biomass.
4.2 Belowground Biomass

The Hedgerow Fallow System has higher belowground biomass than the Open Fallow System at the average of 281.31 kg/ha and 232.80 kg/ha, respectively (Table 2). Their difference is not significant with P-value less than alpha value of 0.05 (Figure 7). However it must be noted that the roots of the tree hedgerows were not sampled as the researcher wanted to maintain the integrity of the tree hedgerow.

Table 2. Amount of Belowground Biomass (kg/ha) generated.

| FARMER COOPERATOR | HEDGEROW FALLOW SYSTEM | OPEN FALLOW SYSTEM |
|--------------------|------------------------|-------------------|
| CODILLA            | 656.36                 | 597.9             |
| RENE               | 131.8                  | 65.3              |
| CUIZON             | 210.5                  | 153.5             |
| PABLING 1          | 219.3                  | 214.8             |
| PABLING 2          | 188.6                  | 132.5             |
| MEAN               | 281.31                 | 232.80            |

Figure 7. Average Belowground Biomass.
4.3. Total Biomass
The Hedgerow Fallow System has higher Total biomass than the Open Fallow System at the average of 109,362.71 kg/ha and 12,749.01 kg/ha, respectively (Table 3). Their difference is significant with P-value less than alpha value of 0.05 (Figure 8 and Appendix E).

The reason for the significant higher value of the hedgerow fallow system on the total biomass than the open fallow system was that the above ground biomass of the hedgerow fallow system is significantly higher than the open fallow system, not only in the aboveground biomass, but also in its total fallow biomass. The reason was already mentioned in section 4.1.

The higher amount of biomass generated in the hedgerow fallow system was expected since there was already a standing biomass in the presence of the tree hedgerows established along the contour when the fallow period begun. Unlike in the open fallow, there were crop residues and some weeds. The tree hedgerows had the advantage of obtaining nutrients and thereby generate more biomass due to its nutrient pumping phenomena [5].

Table 3. Amount of Total Fallow Biomass (kg/ha) generated.

| FARMER COOPERATOR | TOTAL FALLOW BIOMASS, HEDGEROW FALLOW | TOTAL FALLOW BIOMASS, OPEN FALLOW SYSTEM |
|-------------------|---------------------------------------|------------------------------------------|
| CODILLA           | 133,874.19                            | 12,726.10                                |
| RENE              | 163,159.04                            | 2,867.96                                 |
| CUIZON            | 59,431.85                             | 32,080.55                                |
| PABLING 1         | 81,311.74                             | 4,303.90                                 |
| PABLING 2         | 109,036.72                            | 11,766.53                                |
| MEAN              | **109,362.71**                        | **12,749.01**                            |

Figure 8. Total Biomass.

5. Summary, Conclusion and Recommendation
Assessment on the hedgerow fallow system in terms of comparing the amount of biomass produced with the traditional shifting cultivation system, as represented in this study by the open fallow system, is indispensable. That is because biomass plays a key role as the nutrient sink in potentially supplying the nutrients needed for crops especially in the humid tropics where nutrients losses in the soil is high due to intense and frequent rainfall and highly weathered soil which is characterized by good drainage properties and a negative net charged soil. This study has measured the total biomass of the two fallow
systems and compare as to whether the hedgerow fallow system generates more biomass than the open fallow system. Calculation of the total biomass was made possible by measuring the amount of biomass produced on the above and belowground. The total biomass of the hedgerow fallow system was much significantly higher than the open fallow system at the average amount of 109,362.71 kg/ha and 12,749.01 kg/ha, respectively. The reason is because the amount of the above ground biomass of the hedgerow fallow system was significantly higher than that of the aboveground biomass. It also showed that the total biomass of the hedgerow fallow system was significantly higher than the open fallow system. The finding of this study shows that the tree hedgerow biomass is the one factor for the massive amount of biomass generated. Specifically the tree hedgerow biomass contributed about 93% of the total biomass of the hedgerow fallow system. In the light of that, the hedgerow fallow system has the potential in reducing the fallow period without substantially compromising soil fertility; a condition that is critical when land availability is scarce. Should there be more similar studies to be conducted in the future, it is recommended that the roots of the tree hedgerow should also be sampled so as to get a more accurate picture of the belowground biomass.

The hedgerow fallow system has the potential in reducing the fallow period since it generates massive amount of biomass in a shorter period of time. Since fallow vegetation locks up nutrients in its biomass, the massive amount of biomass generated will proportionately store up a higher amount of nutrients needed during the cropping phase. The shortening of the fallow period is most important when land availability is scarce [6].

6. Acknowledgement
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7. Appendices
Appendix A. t-Test: Paired Two Sample for Means of the Aboveground Biomass generated.

|                      | HEDGEROW FALLOW SYSTEM | OPEN FALLOW SYSTEM |
|----------------------|------------------------|--------------------|
| Mean                 | 5.00480                | 3.94196            |
| Variance             | 0.02920                | 0.17582            |
| Observations         | 5                      | 5                  |
| Pearson Correlation  | -0.63909               |                    |
| Hypothesized Mean Difference | 0                  |                    |
| df                   | 4                      |                    |
| t Stat               | 4.36373                |                    |
| P(T<=t) one-tail     | 0.00601                |                    |
| t Critical one-tail  | 2.13185                |                    |
| P(T<=t) two-tail     | 0.01203                |                    |
| t Critical two-tail  | 2.77645                |                    |

Appendix B. Transformed Data of the amount of Carbon stored in the Aboveground Fallow Biomass.

| Farmer Cooperator | Hedgerow Fallow System | Skewness | Kurtosis | Log10 | Skewness | Kurtosis |
|-------------------|------------------------|----------|----------|-------|----------|----------|
| COD               | 125,379.63             | 0.301    | -0.542   | 5.098 | -0.320   | -0.731   |
| REN               | 163,027.24             |          |          |       |          |          |
| CUI               | 108,826.22             |          |          | 5.037 |          |          |
| PAB1              | 59,212.55              |          |          | 4.772 |          |          |
| PAB2              | 80,433.82              |          |          | 4.905 |          |          |

| Farmer Cooperator | Hedgerow Fallow System | Skewness | Kurtosis | Log10 | Skewness | Kurtosis |
|-------------------|------------------------|----------|----------|-------|----------|----------|
### Appendix C. t-Test: Paired Two Sample for Means of the Belowground Biomass generated.

|                | HEDGEROW FALLOW SYSTEM | OPEN FALLOW SYSTEM |
|----------------|-------------------------|--------------------|
| Mean           | 0.99755                 | 0.82539            |
| Variance       | 0.02541                 | 0.05823            |
| Observations   | 5                       | 5                  |
| Pearson Correlation | 0.60200             |                    |
| Hypothesized Mean Difference | 0.00000             |                    |
| Df             | 4.00000                 |                    |
| t Stat         | 1.99241                 |                    |
| P(T<=t) one-tail | 0.05856               |                    |
| t Critical one-tail | 2.13185           |                    |
| P(T<=t) two-tail | 0.11713               |                    |
| t Critical two-tail | 2.77645           |                    |

### Appendix D. Transformed Data in the amount of Belowground Fallow Biomass generated.

| Farmer Cooperator | Hedgerow Fallow System | Skewness | Kurtosis | Log10 Skewness | Kurtosis |
|-------------------|------------------------|----------|----------|----------------|----------|
| CODILLA           | 656.36                 | 2.088    | 4.526    | 2.817          | 1.586    | 3.286    |
| RENE              | 131.80                 |          |          | 2.120          |          |
| PABLING 1         | 210.50                 |          |          | 2.323          |          |
| PABLING 2         | 219.30                 |          |          | 2.341          |          |
| CUIZON            | 188.60                 |          |          | 2.276          |          |
| MEAN              | 281.31                 |          |          | 2.449          |          |

| Farmer Cooperator | Open Fallow System | Skewness | Kurtosis | Log10 Skewness | Kurtosis |
|-------------------|--------------------|----------|----------|----------------|----------|
| CODILLA           | 597.90             | 1.884    | 3.798    | 2.777          | 0.646    | 1.355    |
| RENE              | 65.30              |          |          | 1.815          |          |
| PABLING 1         | 153.50             |          |          | 2.186          |          |
| PABLING 2         | 214.80             |          |          | 2.332          |          |
| CUIZON            | 132.50             |          |          | 2.122          |          |
| MEAN              | 232.80             |          |          | 2.367          |          |
Appendix E. t-Test: Paired Two Sample for Means of the Total Fallow Biomass generated.

|                          | HEDGEROW FALLOW SYSTEM | OPEN FALLOW SYSTEM |
|--------------------------|------------------------|--------------------|
| Mean                     | 5.00623                | 3.95251            |
| Variance                 | 0.02908                | 0.17397            |
| Observations             | 5                      | 5                  |
| Pearson Correlation      | -0.63381               |                    |
| Hypothesized Mean Difference |                       | 0                  |
| df                       | 4                      |                    |
| t Stat                   | 4.35123                |                    |
| P(T<=t) one-tail          | 0.00607                |                    |
| t Critical one-tail      | 2.13185                |                    |
| P(T<=t) two-tail         | 0.01215                |                    |
| t Critical two-tail      | 2.77645                |                    |

Appendix F. Transformed Data in the amount of Total Fallow Biomass generated.

| Farmer Cooperator | Hedgerow Fallow System | Skewness | Kurtosis | Log10 | Skewness | Kurtosis |
|-------------------|------------------------|----------|----------|-------|----------|----------|
| CODILLA           | 126,035.99             | 0.28948  | -0.58777 | 5.10049| -0.32391 | -0.75812 |
| RENE              | 163,159.04             | 5.21261  |          |       |          |          |
| CUIZON            | 109,036.72             | 5.03757  |          |       |          |          |
| PABLELING 1       | 59,431.86              | 4.77402  |          |       |          |          |
| PABLELING 2       | 80,622.42              | 4.90646  |          |       |          |          |

| Farmer Cooperator | Open Fallow System    | Skewness | Kurtosis | Log10 | Skewness | Kurtosis |
|-------------------|------------------------|----------|----------|-------|----------|----------|
| CODILLA           | 12,726.10              | 1.49333  | 2.45406  | 4.10470| 0.11134  | -1.11367 |
| RENE              | 2,867.96               |          |          | 3.45757|          |          |
| CUIZON            | 11,687.53              |          |          | 4.06772|          |          |
| PABLELING 1       | 32,141.85              |          |          | 4.50707|          |          |
| PABLELING 2       | 4,221.60               |          |          | 3.62548|          |          |

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