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# Litter Fall Production in West-African Forests and Plantations

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## Introduction

Tree litter fall is the major above-ground input of carbon (and nutrients) into the forest and plantation floor. Such litter layer protects the underlying humus and mineral soil against drought and represents a considerable buffer improving the ecosystem capacity. However, on a regional scale, litter fall data are scarcely available on sufficient stands as it is a cumbersome task. These are to be collected and analyzed, when estimating carbon budgets and accounting green house gas as requested by international agreements.

To predict litter fall annual quantity of forest and plantation in Benin, West-Africa, vegetation stand parameters like biomass were measured. Previous studies by Sonwa (2004) in Cameroon and Mulindabigwi (2006) in Benin indicated that litter fall depended on factors like latitude, precipitations, basal area and age. Yearly litter fall fluctuated around 6-8 t/ha in Northern Ouémé, Benin (Mulindabigwi) and between 8-14 t/ha under several types of cocoa based agroforests in Cameroon (Sonwa 2004).

The biological stand parameters, however, will not change as strongly as variation of litter fall over time and across regions in Benin, where unimodal and bimodal Guinean Coast climate rainfall regimes dominate differently in North and South. For predicting regionally more generalized and temporal dynamics of litter fall, climate change should be taken into account. Moreover, the micro-site conditions like soil characters vary throughout the regions in Benin could contribute to more precise prediction of litter fall.

## Material and Methods

Litter fall amounts of 6 sites in forest and plantations along the whole North, Middle and South Ouémè River Basin (10°N, 2°E—6°N, 2°E), were collected in a monthly interval for a whole year. Additionally, the litter fall data of other 7 sites within the same project IMPETUS in Benin were used. The biological stand parameters like diameter at breast height (DBH), basal area (BA), height of tree (H), and planting density (PD) were measured in situ. Between 10 and 20 of 1m² litter traps were allocated to each of the 13 sites. The soil samples in the same sites were taken and analyzed in Germany. Climate parameters like 20 years average annual and monthly precipitation amount (1985-2004), number of rainy days, were supplied by Mr. Malte Diederich from the same project.

Data were analyzed with the statistic program STATGRAPHICS Plus 5.1 in 3 steps. Firstly, the time series analyses were done with 2 variables: the monthly litter fall quantities and the average monthly precipitation quantities of 13 sampling sites. Secondly, the multiple regressions with 13 sites data were done. Thirdly, the simple regression analyses were performed with stand, site and climate parameters mentioned above for the own measurements of the 6 sites. Finally, the multiple regression analyses with 6 sites data set were performed for determining the most suitable predicting model for litter fall.

## Results and Discussion

The regression analyses show the following results:

1. Time series analyses of 13 sites data set (Table 1) with 2 variables "Monthly total dry litter fall quantity vs. Monthly precipitation": Over all the 13 sites, there is a statistically significant relationship between 2 variables at the 99% confidence level. The correlation coefficient equals -0.51, indicating a moderately strong relationship between the 2 variables.

**Table1. Litter fall data across 13 sites in Benin as related to different ecological parameters**

| Serial Nr. | LF t/ha | Rain mm | H cm | Veco m³/ha | N-Lat. | E-long. | Elev. |
|---|---|---|---|---|---|---|---|
| Boranglf | 5.67 | 1137 | 380 | 37985 | 7.20 | 2.06 | 183 |
| lafolf | 7.88 | 1185 | 845 | 84516 | 6.98 | 2.13 | 87 |
| latelf | 8.37 | 1185 | 1767 | 176747 | 6.98 | 2.17 | 69 |
| pofolf | 8.00 | 1214 | 1176 | 117579 | 6.97 | 2.68 | 104 |
| nfolf | 7.81 | 1160 | 688 | 68831 | 9.76 | 2.35 | 317 |
| nmglf | 3.58 | 1160 | 760 | 76000 | 9.79 | 2.71 | 394 |
| sefolf | 9.02 | 1283 | 1245 | 124490 | 9.70 | 1.67 | 439 |
| sefalf | 1.72 | 1283 | 514 | 51350 | 9.70 | 1.67 | 439 |
| secashlf | 4.55 | 1283 | 633 | 63330 | 9.70 | 1.67 | 439 |
| dfolf | 4.10 | 1250 | 670 | 67020 | 9.02 | 1.94 | 384 |
| dfalf | 3.02 | 1250 | 514 | 51350 | 9.02 | 1.94 | 384 |
| dcashlf | 2.65 | 1250 | 633 | 63330 | 9.02 | 1.94 | 384 |
| dorlf | 3.78 | 1250 | 700 | 70000 | 9.02 | 1.94 | 384 |

- Boranglf = Bohicon orange, lafolf = Lama forest, latelf = Lama forest, pofolf = Pobè forest, nfolf = N'dali forest, nmglf = N'dali mango, sefolf = Sèrou forest, sefalf = Sèrou fallow, secashlf = Sèrou cashew, dfolf = Dougé forest, dfalf = Dougé fallow, dcashlf = Dougé cashew, dorlf = Dougé orange.

2. Multiple regressions for 12 sites to determine the annual total litter fall quantity (LF kg/ha):
   a. Precipitation, height or latitude alone could determine relatively strongly LF.
   b. 2 or 3 parameters combined yielded some better models. For example:

The following equation

**LF t/ha = 0.00117854*Rain mm + 0.00484474*H cm**

explains 91.1% of the variability in LF. There is a statistically significant relationship between the variables at the 99% confidence level (Figure 1).

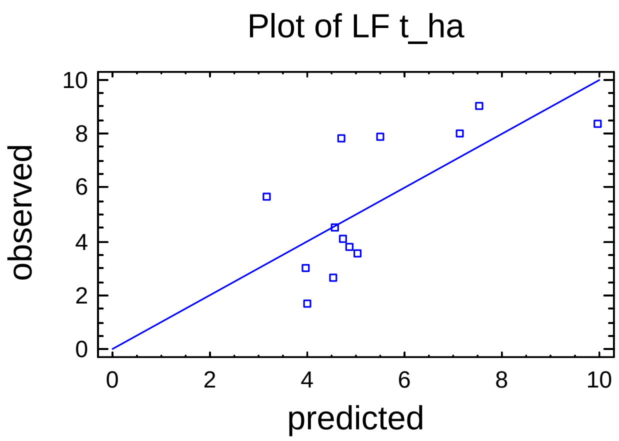


**Figure 1. Relation between annual litter fall and annual precipitation and tree height as independent variables.**

3. Simple regressions for 6 sites to determine LF:
    a. The best single determining variable was a biological stand parameter: Planting density (here the Nr. of trees per hectare), with a correlation coefficient = 0.98 and a R-squared = 97.5 %.
    b. When comparing with other site and climate parameters, the biological stand parameters like bio-volume (Vbio-m3/ha), DBH could fit and explain the LF and its variation better than climate parameter like average annual precipitation.
    c. Within the site parameters, only the elevation related to litter fall was almost as good as Vbio-m and DBH.
    d. The soil parameter carbon percent within 20cm deep soil layer had relative weak relations with LF.

**Table 2: Litter fall across 6 sites in Benin as related to important soil and growth characteristics**

| Serial Nr. | LF kg/ha | Rain mm | DBH cm/tree | Sum BA $m^2$/ha | Height cm | PD | Vbio $m^3$/ha | N-Lat. | E-long. | Elev. | Soil C % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Boranlf | 5675 | 1137 | 11 | 11 | 380 | 215 | 1 | 7.20 | 2.06 | 183 | 0.56 |
| lafolf | 7878 | 1185 | 15 | 20 | 845 | 344 | 6 | 6.98 | 2.13 | 87 | 2.49 |
| latelf | 8371 | 1185 | 28 | 62 | 1767 | 944 | 103 | 6.98 | 2.17 | 69 | 1.25 |
| pofolf | 7998 | 1214 | 10 | 111 | 1176 | 589 | 77 | 6.97 | 2.68 | 104 | 1.34 |
| nfolf | 7807 | 1160 | 17 | 39 | 688 | 656 | 18 | 9.76 | 2.35 | 317 | 0.91 |
| nmglf | 3583 | 1160 | 7 | 8 | 760 | 100 | 1 | 9.79 | 2.71 | 394 | 2.73 |

* Serial Nr. same as in Table 1.

4. Multiple regression for 6 sites to determine the LF:
    a. The annual precipitation was the best single parameter for determining LF.
    b. Even only with one parameter like precipitation, DBH, BA, Planting density, Vbio Height, carbon percent, the fitted models without constant could explain the variability of LF relatively well.

Among all the parameters of 3 categories: biology, climate and site, different combinations of parameters yielded different models with and without constant, which explained easily more than 90% of variability for LF at 99% confidence level, even only with 2 parameters, For example, for the equation

$$\mathbf{LF = 6.42646*PD + 462.14*Latitude}$$

where a statistically significant relationship could be found between the variables at the 99% confidence level. The R-Squared statistic indicates that the model explains 96.1% of the variability in LF.

In another example, the output shows the results of fitting a multiple linear regression model to describe the relationship between LF and 2 independent variables. The equation of the fitted model is:

$$\mathbf{LF = 163.629*DBH + 3.8467*Precipitation}$$

Here again, there is a statistically significant relationship between the variables at the 99% confidence level and a determination coefficient as high as 97.2% (Figure 2).

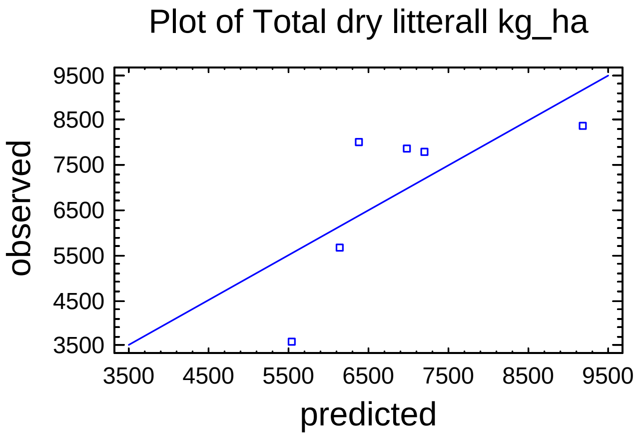


**Figure 2. Predicting model for annual litter fall using tree DBH and annual precipitation as independent variables.**

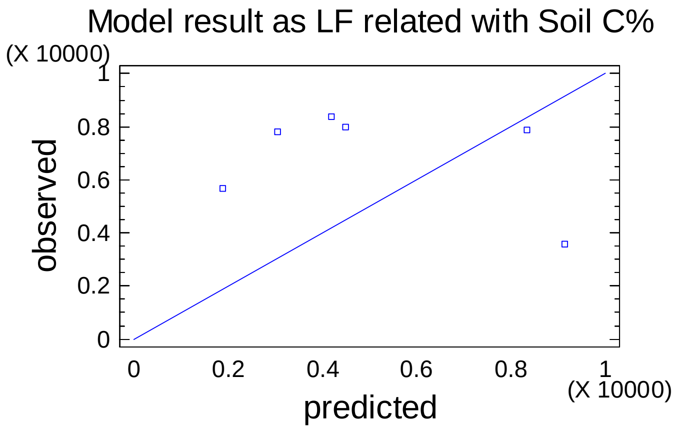


**Figure 3. Relation between soil carbon and annual litter fall quantity.**

The soil carbon content as related to annual litter fall quantity showed a statistically significant relationship at the 95% confidence level. The equation: LF = 3352.72*Soil C % has adetermination coefficient of only 67.5% (Figure 3).

## Conclusion

Tree litter fall is the major above-ground input of carbon (and nutrients) into the forest and plantation floor.

In our studies, the annual litter fall flux has been found to correlate with site, stand, and climate characteristics like planting density, annual precipitation, latitude, DBH, height and to a lesser degree with Carbon content in the soil. This opens the possibility of making models for predicting tree litter fall on regional scale, both in forests and plantations where it is not measured directly.

Since vegetation adapts more to long term climate conditions than short term climate conditions, the monthly dynamic of litter fall quantity is more difficult to predict than annual litter fall quantity. The different rainfall regimes should be taken into account in future research.
However, the results showed that annual litter fall quantity could be reasonably predicted by models fitted with site, stand and climate parameters over the regions with different rainfall regimes. Comparatively to site parameters like soil properties, the biological stand parameters are easy to measure and can be combined with large scale climate parameters to predict annual litter fall dynamics reasonably over the regions.


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