ISSN (Online) : 2455 - 3662
SJIF Impact Factor :3.395 (Morocco)

EPRA International Journal of Multidisciplinary Research

Volume: 2 Issue: 5 May 2016

Published By :
EPRA Journals

EPRA International Journal of Multidisciplinary Research (IJMR) ISSN (Online): 2455-3662

SJIF Impact Factor: 3.395 (Morocco) Volume: 2 Issue: 5 May 2016

DYNAMICS OF LITTERFALL IN NUTRIENT CYCLING AND FOREST PRESERVATION

Sandeep Pandey[1]

[1]Faculty, School of Environmental Biology, A.P.S. University, Rewa, M.P, India

Gulzar Ahmad Sheikh[2]

[2]M. Phil. Scholar, School of Environmental Biology, A.P.S. University, Rewa, M.P, India

Aabid Hussain Bhat[3]

[3]M. Phil. Scholar, School of Environmental Biology, A.P.S. University, Rewa, M.P, India

ABSTRACT

The forest litterfall plays a significant role in regulating global biogeochemical cycles. The production of litter varies in different forest ecosystem across the globe and mainly controlled by vegetation type, phenology and environmental factors. The forest litter with chief constituent as nitrogen, carbon, phosphorus, calcium, potassium helps in increasing soil fertility and moisture and helps in forest recovery and preservation. The litter decomposition process governed by temperature rainfall, quality and composition is more important as it helps in mineralization of dead organic matter into useful substances that becomes a chief constituent of nutrient cycle. Thus litterfall as a carbon stock of different functional type ecosystem is significant in understanding particulate organic matter origin and cycling and global climate change.

KEYWORDS: *litter biomass, carbon stock, biogeochemical cycle, forest regeneration*

INTRODUCTION

Forests ecosystems with a global area of 3999 M ha (FAO, 2015), are the sources of livelihoods to millions of people (Kohl et al., 2015) and are the largest carbon sink on the globe, with more than 50% of their net primary production in form of litter biomass (Domke et al., 2016). Plant litter forming organic matter and mineralization to inorganic carbon forms largest carbon pool (Cotrufo et al., 2015) and accounts for an estimated 5% of all carbon stocks worldwide and contribute significantly in national carbon budgets (Domke et al., 2016). Litterfall is the initial phase of the biogeochemical cycle controlled by climatic factors returning nutrients to the soil and increases as the forest evolves and basal area increases, bringing changes in species phenology and giving rise to different pedogenetic processes (Lebret et al., 2001). In recent years aboveground and belowground forest litter responses to global climate change and their contribution to soil organic carbon sequestration, physico-chemical and biological processes and their interaction with seasonal freeze-thaw cycle and drying-rewetting cycle have got worldwide concern (Yang et al., 2007). Litterfall in tropical forests were observed in spring or winter, corresponding to the dry season; in temperate broadleaved and needle-leaved evergreen forests, it take place at various seasons; and for temperate deciduous broadleaved and boreal evergreen needle-leaved forests, litterfall occurs in autumn, and is determined by physiological and environmental variables (Zhang et al., 2014). The litters obtained from undergrowth and forest soil are also the good reservoir of carbon stock ascertaining forests a more effective sink of carbon (Ullah and Al-Amin, 2012). The litterfall is also an important source of nitrogen and also helps in cycling of other nutrients and is a key mechanism in the management of forest fertility. Its addition increases the forest's nutrient supply and any type of manipulation shows changes in soil and foliar nutrient specially phosphorus concentrations affecting above-ground productivity (Sayer, and Tanner, 2010).

LITTERFALL AND GLOBAL FORESTRY

In broadleaved and coniferous forest, concentration of dissolved and particulate organic carbon and nitrogen fractions and fluxes were higher during the growing than the dormant season. However in broadleaved forest the annual fluxes of C and N were released more during the growing season, in comparision to C and N in the coniferous forest (Mellec et al., 2010). In tropical evergreen forest and tropical dry forest the N and P content of leaves and litter increases with increasing temperatures in compare to mediterranean temperate forest and in tropical dry forest the P content is managed even in limited P supply and in all these three forest ecosystems climatic factors plays a significant role in ecosystem nutrient cycling (Campo et al., 2014). In tropical dry deciduous forest like Indian soil, the litter nutrient contains N, P, Ca, Mg, K and Na are controlled by seasonal variability and among these only potassium exhibits leaching and mobilization and litter helps in production of new foliage and increasing the soil fertility (Kumar et al., 2010).

In dry tropical forests presence of wide range of deciduous condition, like leaflessness duration among dry tropical trees shows large variations in their growing season length mainly due to water stress during summer and as the duration increases, the leaf flushing period decreases but leaf fall period shows little variation. The leaflessness, leaf strategy index, wood density and leaf mass per area shows variation due to functional diversity in tree species in the region. The variation in seasonal duration of leaflessness among species is the reflections of differences in tree functional traits like stem wood density, leaf strategy index and leaf mass per area (Kushwaha et al., 2010). In these forest ecosystem litter carbon concentrations were highest in the early-dry season and decreases in the rainy season, while the rainfall seasonality changes nitrogen concentrations and microbial nitrogen was lowest in the late-dry and highest in the early-rainy seasons. Thus the seasonal changes in nitrogen dynamics were affected by rainfall seasonality and labile carbon availability, and not by microbial biomass. Litter phosphorus was higher in the rainy season compare to early-dry season (Anaya et al., 2007). In Mediterranean forest soil temperature and relative water content accompanied by favorable climatic and edaphic conditions contribute significantly to soil carbon storage, playing an important role in ecosystem functioning (Zribi et al., 2015).

In subtropical evergreen forest nutrient fluxes increase as elevation decrease. The rainfall shows positive correlation at lowest elevation, temperature is the decisive factor at the mid-elevation and both rainfall and temperature controls the litterfall at the highest elevation. The responses of plant community and decrease in nutrient concentration at different elevation gradient may be due to global warming (Lu and Liu, 2012). In moist semi-deciduous forest litterfall had higher concentrations of nitrogen and lower concentration of soluble polyphenols and lignin, standing litter changes are low in comparison to secondary forests and gross litter decomposition decreases during forest conversion and nitrogen and lignin are the best predictors of decomposition (Dawoe et al., 2010). In cold biomes mainly in alpine forest ecosystems the winter warming causes decrease in snowpack seasonality resulting in litter cellulose and lignin degradation and slow down the soil carbon sequestration formation from foliar litter. The winter exhibit highest daily loss rate of litter cellulose and lignin deposition and these changes are mainly affected by interactions among forest gap position, period and species (Li et al., 2016). The global dataset designed to study the leaf-litter of woody plants reveals that nitrogen concentration was highest in Africa and lowest in North America and increases linearly with mean annual temperature and annual precipitation and lowers down with latitude. Dataset also suggest that phosphorus concentrations was more in the Asian mainland compare to Asian islands like Japan and Malaysia and is not influenced by temperature, it decreases linearly with precipitation and shows a convex quadratic relationship with latitude (Kang et al., 2010).

Climate variables like rainfall shows impact on litterfall production (Zhou et al., 2007) and in floodplain forest types litterfall production along a topographic gradient is highest during the large flood and decreasing later depending on flooding pulse (Acenolaza et al., 2010). In agroforestry systems the litterfall production and carbon (C) and nitrogen (N) fluxes is comparatively higher than tropical forests (Negash and Starr, 2013). The litter bag technique is another best method to study leaf litter fall, decomposition and release of nutrients to soil from leaf litter and can be applied for principal tree species in tropical dry deciduous forests (Das and Mondal, 2016). The near infrared reflectance spectroscopy technique with NIRS Systems 5000 spectrophotometer reported that partial least squares is comparatively better than stepwise regression in improving calibrations and gives valid predictions about nitrogen, ash and proximate carbon fractions during the leaf litter decomposition process (Joffre et al., 1992). In semi-arid conditions allometric equations using best-fit models and ash method for estimating aboveground biomass production can be helpful to provide a rapid analyses of wood, leaf and total aboveground biomass production and carbon stock (Bayen et al., 2016). The homegarden agroforests provides better information to growers in selection of indigenous tree species producing litterfall and their decomposition along with the management for an efficient nutrient cycling of the system (Das and Das, 2010).

FOREST LITTER DECOMPOSITION

Litter mixture with leaf litter species composition and relative abundance and universal fungal communities significantly affect forest soil decomposition (Gao et al., 2015). Litter decomposition helps in breaking down dead organic material into smaller size particles and organic materials are mineralized into prime constituents like H_2O, CO_2 and mineral components. During this process, recalcitrant organic compounds are formed and carbons get leached to the mineral soil. The decomposition occurs due to leaching of soluble organic compounds into the soil, fragmentation of litter into small sizes and catabolism by decomposers (Cotrufo et al., 2010). Litter quality and occurrence of season, are the most important regulators of litter decomposition in forests (Gautam et al., 2007). Availability of soil nutrients is a significant factor controlling short-term and long-term litter decomposition, single-species decomposition vs. mixed-litter decomposition and litter nutrients formation. The quantity of litter input and its interaction with the soil control the formation of soil organic carbon, and the effects of soil fertility on litter decomposition vary with changes in environmental conditions (Ge et al., 2013). Litters of different functional types and chemical quality uses strategy of slow decomposition and nutrient mobilization showing alternate stage of rapid mineralization followed by slow immobilization and generally in the order of $K > Mg > Ca > N \approx P$ (Gautam et al., 2016).

The litter decomposition is influenced by macroclimate like temperature (Zhou et al., 2007) and evapotranspiration (Zhou et al., 2008), soil fauna (Shaojun et al., 2010) and substrate quality and power of substrate quality is lower in the tropics than that in boreal-to-cool temperate regions. In these regions, there is a synergistic relationship between litter quality, decay rates in litterbags and substrate turnover rates across different vegetation types such as conifers and deciduous trees and species with higher light penetration have higher understorey temperature and higher quality litter compared to trees with lower light penetration (Rahman and Tsukamoto, 2015). In subtropical evergreen broad-leaved forest the nutrient released during litter decomposition are Ca, Mg and Mn and their initial concentrations and precipitation are the important factors that influences the decomposition of foliar litter (Ma et al., 2015). In deciduous broadleaved and evergreen broadleaved forest occurring in warm temperate regions moisture shows a crucial effect on litter decomposition and the activities of microorganisms and surface-living earthworms are affected by the water content on the two functional types. The power of substrate quality in evergreen broadleaved and deciduous broadleaved forest was smaller compare to coniferous forests and deciduous broadleaved forest in boreal-to-cool temperate regions (Rahman and Tsukamoto, 2013).

The rate of litter decomposition is related to the initial chemical composition of the litter and several constituents like N, Ca, water soluble compounds, total nonstructural carbohydrates, lignin, acid, detergent, cell wall components and fibre showed a significant relation with decomposition. The effect of nitrogen decreases while that of lignin increases with time and both of these are responsible for variability in the annual weight loss. The climatic factor like rainfall and temperature influences 80 % of the variability in monthly forest litter weight loss (Pandey and Singh 1982). The carbon and nutrient fluxes rates and pattern in forest litter is affected by the efficiency of nutrient use. The species that returns the most mass did not return most P, N, or cations and depends on the amount of N and P resorption before leaf fall. The species shows variation in the ecophysiological response due to edaphic and climatic conditions and heavy winds or the heavy rains, forces the shedding of non-senesced leaves. Although the amount of this higher quality material is less but it can provide a small quantity of nutrients to the forest floor community. The area with less water availability have temporal variations in forest floor leaf litter due to varied responses of species to different environmental conditions (Cuevas and Lugo, 1998).

The process is significantly influenced by atmospheric nitrogen deposition and any external treatment of nitrogen to single-species litter or litter mixture decomposition shows a remarkable responses and changes in chemical composition preferably due to decrease in the substrate C:N ratio (Wang et al., 2015). Elevation gradient plays a significant role in litter decomposition and it decrease across the elevation gradient, The low elevation forests warm and humid microclimate favors decomposer activities and decomposer community are adapted to consume large amounts of leaf litter (Wang et al., 2010). The litterfall and litter component carbon, nitrogen and lignin increase in the old-growth forest and exhibits a directional change in the forest floor C and N cycling rates mainly due to foliar litter production and proportions in the total litterfall which causes by changes in dominant tree species biomass and therefore plays a dominant role in regulating litter chemistry and quantity of the forest floor (Xuefeng et al., 2010).

SIGNIFICANCE OF LITTERFALL

The litter decomposition process shows close correlation with nutrient cycling and maintains the soil fertility in the forest ecosystem (Wang et al., 2015, Ge et al., 2013). Evaluation of forest litterfall helps in understanding nutrient cycle, forest growth, succession pathways, and interactions with environmental variables (Zhou et al., 2007). The potential nutrient return in warm ecosystem shows delay in leaf fall due to phenological factors and climatological variations with the lowest rainfall, particularly with respect to P and Ca (Gallardo et al., 1998). Forest canopy is an important source for particulate organic matter. Pollen accumulation, insect excretions and deposited organic matter mobilised by dry/wet precipitation plays a significant role in the formation of dissolved organic matter and particulate organic matter and mainly effected by tree species, seasonality and biotic agents (Mellec et al., 2010). According to leaf-litter global dataset for modeling biogeochemical cycles in different eco-regions on a global scale, the leaf-litter N:P ratio should be taken into consideration as it follows a positive linear relationship with temperature and precipitation and exhibits a concave quadratic response with latitude for different functional groups like shrubs, evergreen broadleaf, deciduous broadleaf and conifers (Kang et al., 2010).

The decomposition process controlled by biotic factors like decomposers and litter types and abiotic factors like temperature moisture (Wang et al., 2010) climate and soil organisms that releases nutrient during its decomposition have shown a great impact on global climate change due to increase in atmospheric carbon dioxide concentration and temperature (Yang et al., 2007).

During forest recovery as the secondary succession precedes the mean leaf area, water content and mean leaf dry weight per unit area of primary species increases compared to secondary species along with decline in foliar nitrogen, phosphorus, and potassium in early secondary forest (Kappelle and Leal, 1996).The evaluation of litter production, temporal variation, rate of decomposition and nutrient cycling helps to analyze biological potential of a species to aid soil biological restoration. It is necessary that plantation of fast growing tree, with a fast canopy closure and species producing large amounts of rapidly decomposing mulch with large amount of nutrients which can be released into the soil at a high rate are the best practices (Ceccon et al., 2015). The microbial pathogens like fungi, bacteria, actinomycetes, viruses and nematodes are components of forest floor and plays an important role in leaf litter decomposition that are formed by leaf fall and wood of fallen trees. Thus the forest litters are the home for saprophytes and saprobionts, and maintains soil health (Ndarake and Umunna, 2015).

In conclusion, litters are the energy bank of forest floor regulating biogeochemical cycle and controlling forest succession, recovery, productivity and preservation. The forest litters are important sources of nitrogen, carbon, phosphorus, calcium, moisture, lignin, fiber etc and its decomposition helps in converting dead organic matter into useful minerals. The litterfall as carbon stock and their impact on climate change are two key issues that should be given special account to assess and evaluate the global environmental changes.

REFERENCES

1. *Acenolaza P.G., Lisandra P.Z., Rodriguez E.E. and Gallardo J.F. (2010) Litterfall production in forests located at the Pre-delta area of the Paraná River (Argentina) Ann. For. Sci., 67(3) pp. 311-311.*
2. *Anaya C.A., García-Oliva F., Jaramillo V.J. (2007) Rainfall and labile carbon availability control litter nitrogen dynamics in a tropical dry forest Oecologia 150 pp. 602–610 DOI 10.1007/s00442-006-0564-3.*
3. *Bayen P., Bognounou F., Lykke A.M., Oue´draogo M., Thiombiano A. (2016) The use of biomass production and allometric models to estimate carbon sequestration of Jatropha curcas L. plantations in western Burkina Faso, Environ Dev Sustain 18 pp143–156 DOI 10.1007/s10668-015-9631-4.*
4. *Campo J., Gallardo J.F., Hernández G. (2014) Leaf and litter nitrogen and phosphorus in three forests with low P supply Eur. J. For. Res., 133(1) pp 121-129.*
5. *Ceccon E., Sa´nchez I., Powers J.S. (2015) Biological potential of four indigenous tree species from seasonally dry tropical forest for soil restoration Agroforest Syst 89 pp 455–467 DOI 10.1007/s10457-014-9782-6.*
6. *Cotrufo M.F., Galdo I.D. and Piermatteo D. (2010) Litter decomposition: concepts, methods and future perspectives pp. 76-90 Soil Carbon Dynamics An Integrated Methodology Ed. Werner L. Kutsch, Michael Bahn and*

Andreas Heinemeyer Cambridge University Press Chapter DOI: http://dx.doi.org/10.1017/CBO9780511711794.006.

7. *Cotrufo M.F., Soong J.L., Horton A.J, Campbell E.E., Haddix M.L., Wall D.H. and Parton W.J. (2015) Formation of soil organic matter via biochemical and physical pathways of litter mass loss Nature Geoscience 8 pp 776–779 doi:10.1038/ngeo2520.*
8. *Cuevas E and Lugo A E. (1998). Dynamics of organic matter and nutrient return from Litterfall in stands of ten tropical tree plantation species. For. ecology management, 112 pp 263–279.*
9. *Das C. and Mondal N.K. (2016) Litterfall, decomposition and nutrient release of Shorea robusta and Tectona grandis in a sub-tropical forest of West Bengal, Eastern India J. For. Res. DOI 10.1007/s11676-016-0208-3.*
10. *Das T and Das A.K. (2010) Litter production and decomposition in the forested areas of traditional homegardens: a case study from Barak Valley, Assam, northeast India Agroforest Syst 79 pp 157–170 DOI 10.1007/s10457-010-9284-0.*
11. *Dawoe E.K., Marney E. I., James Quashie-Sam. (2010) Litterfall and litter nutrient dynamics under cocoa ecosystems in lowland humid Ghana Plant Soil 330 pp 55–64. DOI 10.1007/s11104-009-0173-0.*
12. *Domke G.M., Perry C.H., Walters B.F., Woodall C.W., Russell M.B., Smith J.E. (2016) Estimating litter carbon stocks on forest land in the United States. Sci Total Environ. 24 pp 557-558:469-478. doi: 10.1016/j.scitotenv.2016.03.090.*
13. *FAO, 2015. Global Forest Resources Assessment 2015.*
14. *Gallardo J.F., Gallardo A.M.F., Martin A. and Ignacio S.R. (1998) Nutrient cycling in deciduous forest ecosystems of the Sierra de Gata mountains: aboveground litter production and potential nutrient return Ann. For. Sci., 55 (7) pp 749-769.*
15. *Gao J., Kang F., Li T., Song X., Zhao W., Yu X. and Han H. (2015) Assessing the Effect of Leaf Litter Diversity on the Decomposition and Associated Diversity of Fungal Assemblages Forests 6(7) pp 2371-2386; doi:10.3390/f6072371.*
16. *Gautam M.K., Lee K.S., Song B.Y., Lee D., Bong Y.S. (2016) Early-stage changes in natural 13C and 15N abundance and nutrient dynamics during different litter decomposition, J Plant Res. Feb 25. [Epub ahead of print].*
17. *Ge X., Zeng L., Xiao W., Huang Z., Geng X. and Tan B. (2013) Effect of litter substrate quality and soil nutrients on forest litter decomposition: A review Acta Ecologica Sinica 33(2) pp 102–108.*
18. *Joffre R., Gillon D., Dardenne P., Agneessens R. and Biston R. (1992) The use of near-infrared reflectance spectroscopy in litter decomposition studies Ann. For. Sci. 49(5) pp 481-488 DOI: 10.1051/forest:19920504.*
19. *Kang H., Xin Z., Berg B., Burgess P.J., Liu Q., Liu Z., Li Z. and Liu C. (2010) Global pattern of leaf litter nitrogen and phosphorus in woody plants Ann. For. Sci. 67 pp 811 DOI: 10.1051/forest/2010047.*
20. *Kappelle M. and Leal M.E. (1996) Changes in leaf Morphology and foliar nutrient status along a successional gradient in Costa Rican upper montane Quercus forest. Biotropica, 28 pp 331–344.*
21. *Köhl M., Lasco R., Cifuentes M., Jonsson O., Korhonen K.T., Mundhenk P., Navar J de Jesus., Stinson G. (2015) Changes in forest production, biomass and carbon: Results from the 2015 UN FAO Global Forest Resource Assessment, Forest Ecology and Management, 352(7) pp 21-34.*
22. *Kumar N., Kumar J.I., Bhoi R.N. and Kumar R. (2010) Seasonal changes of bioelements in litter and their potential return to green leaves in five species of tropical dry deciduous forest, western India J For Res,21(1) pp 33-38.*
23. *Kushwaha C.P., Tripathi S.K., Singh G.S. and Singh K.P. (2010) Diversity of deciduousness and phenological traits of key Indian dry tropical forest trees Ann. For. Sci. 67(3) 310.*
24. *Lebret M., Nys C. and Forgeard F. (2001) Litter production in an Atlantic beech (Fagus sylvatica L.) time sequence Ann. For. Sci. 58(7) pp 755-768.*
25. *Li H., Wu F., Yang W., Xu L., Ni X., He J., Tan B., Hu Y. (2016) Effects of Forest Gaps on Litter Lignin and Cellulose Dynamics Vary Seasonally in an Alpine Forest Forests 7(2) 27 doi:10.3390/f7020027.*
26. *Lu Shu-Wei. and Liu Chiung-Pin. (2012) Patterns of litterfall and nutrient return at different altitudes in evergreen hardwood forests of Central Taiwan Ann For Sci 69 pp 877–886 DOI 10.1007/s13595-012-0213-4.*
27. *Ma Z.L., Gao S., Yang W.Q., Wu F.Z. (2015) Seasonal release characteristics of Ca, Mg and Mn of foliar litter of six tree species in subtropical evergreen broadleaved forest. Ying Yong Sheng Tai Xue Bao. 26(10) pp 2913-20.*
28. *Mellec A.L., Meesenburg H. and Michalzik B. (2010) The importance of canopy-derived dissolved and particulate organic matter (DOM and POM) – comparing throughfall solutionfrom broadleaved and coniferous forests Ann. For. Sci. 67 (4) 411.*
29. *Ndarake B.I. and Umunna O.E. (2015) Review of Soil Microbial Flora Associated with Forest Floor Litter in Tropical Rainforest Zone- A Case in South Eastern Nigeria Int J Res Agri For., 2(3) pp 26-30.*
30. *Negash M. and Starr M. (2013) Litterfall production and associated carbon and nitrogen fluxes of seven woody species grown in indigenous agroforestry systems in the south-eastern Rift Valley escarpment of Ethiopia Nutrient Cycling Agroeco 97(1) pp 29-41.*
31. *Pandey U. and Singh J.S. (1982) Leaf-Litter Decomposition in an Oak-Conifer Forest in Himalaya: The Effects of Climate and Chemical Composition Forestry 55(1) pp 47-59 doi:10.1093/forestry/55.1.47.*

32. *Rahman M.M. and Tsukamoto J. (2015) Opposing effects of substrate quality and site factors on forest floor turnover rates: an example from the tropics, Forestry 88 (2) pp 190-199.*
33. *Rahman M.M. and Tsukamoto J. (2013) Leaf traits, litter decomposability and forest floor dynamics in an evergreen- and a deciduous-broadleaved forest in warm temperate Japan, Forestry 86 (4) pp 441-451.*
34. *Sayer E.J. and Tanner E.V.J. (2010), Experimental investigation of the importance of litterfall in lowland semi-evergreen tropical forest nutrient cycling. J Eco, 98 pp 1052–1062. doi:10.1111/j.1365-2745.2010.01680.x*
35. *Shaojun W., Honghua R. and Yong H. (2010) Effects of microclimate, litter type, and mesh size on leaf litter decomposition along an elevation gradient in the Wuyi Mountains, China Ecological Research 25(6) pp1113-1120. DOI: 10.1007/s11284-010-0736-9.*
36. *Ullah M.R. and Al-Amin M. (2012) Above- and below-ground carbon stock estimation in a natural forest of Bangladesh, J For Sci, 58(8) pp 372–379.*
37. *Wang J., Bu W., Zhao B., Zhao X., Zhang C., Fan J., Gadow K. (2015) Effects of Nitrogen Addition on Leaf Decomposition of Single-Species and Litter Mixture in Pinus tabulaeformis Forests. Forests 6(12) pp 4462-4476; doi:10.3390/f6124381.*
38. *Xuefeng L., Yanling H., Shijie H., Ying L., Yan Z. (2010) Litterfall and litter chemistry change over time in an old-growth temperate forest, northeastern China Ann Forest Sci 67(2) pp 206-206.*
39. *Yang W.Q., Deng R.J., Zhang J. (2007) Forest litter decomposition and its responses to global climate change, Ying Yong Sheng Tai Xue Bao. 18(12) pp 2889-95.*
40. *Zhang H., Yuan W., Dong W. and Liu S. (2014) Seasonal patterns of litterfall in forest ecosystem worldwide Ecological Complexity, 20 pp 240–247.*
41. *Zhou G., Guan L., Wei X., Zhang D., Zhang Q., Yan J., Wen D., Liu J., Liu S., Huang Z., Kong G., Mo J. and Yu Q. (2007) Litterfall production along successional and altitudinal gradients of subtropical monsoon evergreen broadleaved forests in Guangdong, China Plant Ecol 188 pp 77–89. DOI 10.1007/s11258-006-9149-9.*
42. *Zhou G., Guan L., Wei X., Tang X., Liu S., Zhang J.L.D. and Yan J. (2008) Factors influencing leaf litter decomposition: an intersite decomposition experiment across China, Plant Soil 311 pp 61–72. DOI 10.1007/s11104-008-9658-5.*
43. *Zribi L., Mouillot F., Gharbi F., Ourcival Jean-Marc. and Hanchi B. (2015) Warm and Fertile Sub-Humid Conditions Enhance Litterfall to Sustain High Soil Respiration Fluxes in a Mediterranean Cork Oak Forest Forests, 6 pp 2918-2940; doi:10.3390/f6092918.*