**Dear reviewers,**

**we appreciate your constructive comments. In the following we provide a line by line response to each of your comments.**

<u>Reviewer #1:</u>

This paper aims to investigate soil and plant nutrient status of beech forests along the precipitation gradient. The experimental design and data presented in this manuscript are very interesting and worth for reporting. Authors were successful to show clear patterns and reasonable discussion as a whole. However the data are not entirely satisfactory to be evidence for possible mechanisms. Some data shown in this study are already published in previous papers by authors and original data of this study seems too narrow.

**You are right that some of the data has already been published elsewhere; we included it to the current manuscript (with reference), as we felt that some of the results of the present manuscript will be easier understandable with a direct reference to the formerly published data. In the next version of the manuscript we will omit the presentation of this data ($\delta^{13}C$ in sun leaves in table 1 and the relationship between precipitation and leaf and fine root mass in Fig. 3).**

**However, we are surprised that you think that the original data of this manuscript is too narrow, as it includes novel, extensive and unpublished data on the influence of precipitation on major soil nutrient pools (net N mineralization, net nitrification, bases, nutrient ratios etc.), as well as on foliar (among others $\delta^{15}N$ in sun leaves) and root contents and resorption efficiencies of the same nutrients in 14 mature beech forests. It is a unique approach to illustrate the effects of reduced precipitation amounts on the nutrient supply of European beech forests.**

Furthermore the manuscript includes many problems and need considerable revisions as follows. The manuscript needs considerable revision before publishing.

Major points:

1. N deposition of study sites

   Differences in precipitation may affect N deposition among sites. Furthermore location of sites may also affect N deposition (i.e. distance from industrial area etc.). However the manuscript did not show N deposition data and detail location of each site. Authors should show deposition data or reasonable references and state explanation how deposition affects the results of this study.

   **We agree that differences in precipitation amounts and location may have affected N deposition amounts. In the next version of the manuscript we will include data on N deposition as derived from the MAPESI model (Builtjes et al. 2011) which includes wet, occult, and dry N deposition estimated for deciduous forests in Germany (1 x 1 km$^2$ grid cells; confidence interval ± 0.3). According to the results of MAPESI, N deposition decreased from the west (3.6 g m$^{-2}$ yr$^{-1}$) to the east (2.2 g m$^{-2}$ yr$^{-1}$) across our precipitation gradient. The**

**decrease by ~40 % along the transect will be discussed in its relevance for N availability in the Discussion section.**

***Builtjes P, Hendriks E, Koenen M, Schaap M, Banzhaf S, Kerschbaumer A, Gauger T, Nagel H-D, Scheuschner T, Schlutow A (2011) Erfassung, Prognose und Bewertung von Stoffeinträgen und deren Wirkung in Deutschland (MAPESI – Modelling of Air Pollutants and Ecosystem Impacts). Umweltbundesamt, Dessau-Rosslau.***

2. Plant sampling
   Leaf N and P concentration may vary among years. However authors calculated resorption efficiency using different year's data. Authors should state reasonable explanation about this.

   **Due to the high number of study sites we were unable to conduct all measurements within one study year, i.e. leaf litter analyses were conducted in an earlier year. As a consequence, calculated resorption efficiencies have to be regarded as an approximation. We will phrase this difference more carefully in the revised version of the manuscript.**

3. N and P availability
   This study hypothesized that precipitation mediated soil acidity gradient affect soil and plant nutrient status. However N mineralization rate and resin P which are index of N/P availability did not show clear trend along the precipitation gradient in spite plant leaves show trends. I suppose method for assessment of N and P availability of this study was not satisfied ones. Authors did only twice *in situ* incubation for N and one time for resin P for upper mineral soils. As authors mentioned in the manuscript, plant can use N and P in organic layers. For organic layers, authors showed total content of N and P in organic layer which was not suitable for N and P availability assessment. Authors should do more detailed discussion for relationship between soil (include organic layer) N and P availability and plant nutrient status, and possible mechanisms about the results. Furthermore increasing root biomass also can affect plant nutrient status even when soil nutrient availability decreased. In this study, fine root biomass was higher in low availability sites. This may mitigate nutrient limitation in low availability sites. Authors should do more detailed discussion in this context.

   **The content of $P_{resin}$ in soil is mainly determined by the pH and by the amount of clay minerals and is therefore relatively independent from seasonal fluctuations. It is standard procedure to analyze $P_{resin}$ once in the growing season in the surface soil as we did (e.g. Sartori et al. 2007, Groffman & Fisk 2011, Vandecar et al. 2011). There is currently no adequate *in situ* method for the analysis of P mineralization (laboratory methods include the application of $^{33}P$). One approach to the measurement of P availability is therefore the analysis of $P_{resin}$ in mineral soil combined with $P_t$/nutrient ratios in the organic layer. We will include a more detailed discussion of this constraint in the text, as well as on the effect of increased fine root biomass at low availability sites on nutrient uptake rates.**

***Groffman PM, Fisk MC (2011) Phosphate additions have no effect on microbial biomass and activity in a northern hardwood forest. Soil Biology & Biochemistry 43: 2441-2449.***

***Sartori F, Markewitz D, Borders BE (2007) Soil carbon storage and nitrogen and phosphorous availability in loblolly pine plantations over 4 to 16 years of herbicide and fertilizer treatments. Biogeochemistry 84: 13-30.***

***Vandecar KL, Lawrence D, Clark D (2011) Phosphorus sorption dynamics of anion exchange resin membranes in tropical rain forest soils. Soil Science of America Journal 75: 1520-1529.***

**Net N mineralization is subject to seasonal fluctuations driven mainly by temperature and soil moisture fluctuations. Ellenberg et al. (1986) found seasonal peaks of the N mineralization rate in April/May and July/August in a beech forest in the Solling Mountains of our study region; we thus chose these months for our measurements. Due to the high number of study sites we were unable to analyze net N mineralization throughout the whole year, so we cannot deduce to yearly rates. But we believe we have sufficiently illustrated peak N mineralization rates in the organic layer and mineral soil (to 10 cm depth) in the growing season of the investigated sites, adequate for comparing climatic influences on N mineralization rates: in a related earlier study we showed that differences in soil moisture, which can be a driver of differences in net N mineralization rates, develop only later in summer, typically not before July/August (Meier & Leuschner 2008). Temperature differences and different start of the growing season along the transect are covered by our first sampling date.**

***Ellenberg H, Mayer R, Schauermann J (1986) Ökosystemforschung. Ergebnisse des Sollingprojekts 1966-1986. Ulmer, Stuttgart.***

***Meier IC, Leuschner C (2008) Leaf size and leaf area index in Fagus sylvatica forests: competing effects of precipitation, temperature, and nitrogen availability. Ecosystems 11: 655-669.***

4. N and P limitation
   According to the results of leaf N/P ratio, I suppose studied forests are under "relative" P limitation in the sense of NP ratio studies such as Koerselman and Meuleman 1996 J.appl. Ecol33:1441-1450 and Güsewell 2004 New Phytol. 164:243-266. Please discuss the results of this study in the context of N and P limitation.

   **The study by Koerselman & Meuleman (1996) identified an N/P ratio > 16 as an indicator of P limitation in wetland ecosystems. Güsewell (2004) found that optimal N/P ratios are species dependent and that P limitation often corresponds to an N/P ratio of > 20. The investigated beech stands of our study had foliar N/P ratios of 33-44 mol mol$^{-1}$, which should indicate relative P limitation, as you have pointed out correctly. It has to be considered, however, that trees may differ in their optimal N/P ratio from herbaceous plants. We will rephrase the corresponding text passages accordingly.**

   **The last sentence of the abstract will be phrased as: "More effective tree-internal N cycling and the decreasing foliar N/P ratio towards the dry stands indicate that the importance of P limitation for tree growth declines with decreasing precipitation."**

Minor points:

P11903 L13: Please show location of each sites. **Done.**

P11903 L17-20: Please show stand structure of each sites. **Done.**

P11905: Soils samples sieved or nor? **Sieved.**

Reviewer #2:

This study tried to clarify nutrient dynamics in beech forests along a precipitation gradient. I believe that conducted researches potentially have merit and are of interest for the readers of "Biogeosciences", however, some major problems do not make this paper convincing.

The most serious problem was very incomplete data presentation. Since the central objective of this study was to clarify nutrient dynamics in beech forests along a precipitation gradient, it was too unkind for the readers not to show their results along the precipitation gradient (Figures did not cover the entire data). Instead of only showing correlations between precipitation and biogeochemical parameters and/or regression models, the authors should show their results completely.

**We agree with you and will include a table with average site values for the investigated biogeochemical parameters additional to the correlations/regressions.**

The authors used both the trend along the precipitation gradient and the comparison between two extremes (sites with > 900mm and those with < 600mm) for their data presentation. However, the comparison between two extremes was the extraction of partial data based on an arbitrary classification, and would not be valid. Therefore, in the present condition, the readers could not recognize the validity of discussion in this paper.

**We agree with you that the assignment to the extremes is to some degree arbitrary. We will therefore omit this type of presentation in the revised version of the manuscript.**

The description of "Materials and methods" was also incomplete. For example, for the sample preparation and chemical analyses of soils, a more concrete description was needed. For statistical analyses, there was no description for correlations, and the readers could not understand whether correlations and regressions were analyzed for mean values or not. I could not find the results of ANOVA with post hoc test in the manuscript.

**We apologize for the inadvertence and will complete the materials and methods section.**

In addition, for the second hypothesis ("the accumulation of organic matter on the forest floor and the built-up of nutrient stores in the organic layers is reduced in a drier climate"), the readers could not understand why the authors could hypothesize this in the present "Introduction". This was partly because there seemed to be a contradiction between the second and third hypotheses. The authors needed to clarify the connections between a precipitation gradient and their hypotheses.

**The second hypothesis aims at a projected lower productivity in drier stands, which will lead to decreased litter input and less organic matter accumulation on the forest floor, i.e. consequently to smaller nutrient stores in the organic layer in these forest stands (assuming at least similar decomposition rates). The third hypothesis aims at drought effects on the nutrient cycle and nutrient availability: reduced precipitation and soil moisture reduce (1) mineralization (Gorissen et al. 2004, Sardans & Peñuelas 2005, 2007) and (2) the diffusion of mobile ions such as nitrate in the rhizosphere (Kreuzwieser & Gessler 2010), (3) change the growth and activity of mycorrhizal hyphae (Rillig et al. 2002) with possible effects on the uptake rate of the fungal partner (Jakobsen et al. 1992, Dickie et al. 2009) and (4) may reduce the uptake capacity of roots for nutrients such as**

**N and P (Gessler et al. 2005, Nahm et al. 2006). We will improve the introduction of these hypotheses in the revised version of the text.**


***Dickie IA, Richardson SJ, Wiser SK (2009) Ectomycorrhizal fungal communities and soil chemistry in harvested and unharvested temperate Nothofagus rainforests. Can J For Res 39: 1069-1079.***

***Gessler A, et al. (2005) Climate and forest management influence nitrogen balance of European beech forests: microbial N transformations and inorganic N uptake capacity of mycorrhizal roots. Eur J For Res 124: 95-111.***

***Gorissen A, et al. (2004) Climate change affects carbon allocation to the soil in shrublands. Ecosystems 7: 650-661.***

***Jakobsen I, Abbott LK, Robson AD (1992) External hyphae of vesicular-arbuscular mycorrhizal fungi associated with Trifolium subterraneum L. New Phytol 120: 371-380.***

***Kreuzwieser J, Gessler A (2010) Global climate change and tree nutrition: influence of water availability. Tree Physiol 30: 1221-1234.***

***Nahm M, Radoglu K, Halyvopoulos G, Gessler A, Rennenberg H, Fotelli MN (2006) Physiological performance of beech (Fagus sylvatica L.) at its southeastern distribution limit in Europe: seasonal changes in nitrogen, carbon and water balance. Plant Biol 8: 52-63.***

***Rillig MC, Treseder KK, Allen MF (2002) Global change and mycorrhizal fungi. In: Van der Heijden MGA, Sanders I (eds.) Mycorrhizal ecology. Ecol Stud 157. Springer, Berlin, pp. 135-160.***

***Sardans J, Peñuelas J (2005) Drought decreases soil enzyme activity in a Mediterranean holm oak forest. Soil Biol Biochem 37: 455-461.***

***Sardans J, Peñuelas J (2007) Drought changes phosphorus and potassium accumulation patterns in an evergreen Mediterranean forest. Funct Ecol 21: 191-201.***


**We would like to thank you for your suggestions to improve this manuscript.**