Empirical and model derived respiration responses to climate in different soils of an arid South African ecosystem

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This study examined the magnitude of soil CO2 efflux in an arid South African ecosystem, the flux responses as well as those of key limiting nutrients to soil temperature increases and moisture reductions consistent with a future climate change scenario, and compared measured soil respiration rates with those predicted with empirically and theoretically-based soil respiration models. Measurements of soil respiration rate, temperature, moisture, N and P contents were conducted monthly over a 12-month period in natural environments and those artificially manipulated with replicated open-top warming chambers (average 4.1oC increase) and precipitation exclusion chambers (average 30.1% decrease in rainfall, 26.2% decrease in fog and dewfall) distributed in five different soil-vegetation units.Measured soil respiration rates were over 3-fold less than those reported for temperate and tropical forest ecosystems with 61.5% of the total soil CO2 efflux contributed by root respiration (derived from the differences between moderately vegetated and sparsely vegetated areas) in moderately vegetated soils. Massive increases (up to 15 times) in soil CO2 efflux occurred during wet phases, but even these large CO2 pulses were only comparable in magnitude with soil CO2 effluxes reported for temperate semi-arid grasslands. There was considerable intra-annual and inter-site variability in the magnitude and direction of soil respiration and N and P responses to elevated temperatures and reduced precipitation levels with poor correspondence evident between soil CO2 efflux and soil organic matter content. Soil CO2 effluxes declined in response to precipitation exclusion by 7.1% over all sites and increased in response to warming by 42.1% over all sites. The large increase in response to warming was assisted by a 7.5% enhancement in soil moisture content due to precipitation interception by the chamber walls and its channelling to the soil surface.Relatively smaller respiration increases in response to warming occurred in moderately vegetated soils, these attributed to soil thermal insulation by the plant canopy cover. Soil P and N contents increased in response to warming by 11.3% and 13.3% respectively over all sites, with soil P declining in response to precipitation exclusion by 5.8% over all sites and soil N increasing in response to precipitation exclusion over all sites by 5.8%. Standard least squares regressions quantified the relationships between soil respiration rate and measured soil physical and chemical properties, and their interactions for each of the 5 soil-vegetation units. These relationships were incorporated in an empiricallybased soil respiration (EMR) model which was compared with a theoretically based generalized soil respiration model (GRESP). GRESP model functions included measured Q10 coefficients at soil moisture contents above field capacity, these assumed reduced by half for dry conditions, and maximum retentive and field capacities of soils. EMR modelled soil respiration rates displayed slightly better correspondence with measured soil respiration rates than GRESP modelled soil respiration rates. This apparent from the higher regression coefficients and lower sums of squared residuals, with EMR model residuals also more closely approximating normal distributions. However, despite the EMR model's slight superiority, it was concluded that more precise laboratory-based measurements of soil retentive and field capacities and their Q10 coefficients at different soil moisture contents could improve the GRESP model's accuracy thereby providing a more convenient and uncomplicated means of predicting respiration responses to current and future climates over a wide range of arid soil types