GENERAL INTRODUCTION

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) concludes that global climate change is a given fact and that human activities since the industrialization influence the global warming with very high confidence (IPCC, 2007). The most important anthropogenic greenhouse gas is carbon dioxide (CO_2). In 2007, the atmospheric CO_2 concentration was 383 ppm, approximately 37% above the concentration at the start of the Industrial Revolution (about 280 ppm in 1750). The rise in atmospheric CO_2 concentration is driven by emissions of CO_2 from fossil fuel combustion and cement manufacturing is responsible for more than 75% of the increase in atmospheric CO_2 concentration. The remainder of the increase comes from land-use changes dominated by deforestation and associated biomass burning with contributions from changing agricultural practices (IPCC, 2007).

The most important consequence of this rise in atmospheric CO_2 concentration is warming the surface temperature of the Earth. Global mean surface temperatures have risen by 0.74 ± 0.18 °C over the last 100 years (1906-2005) and will continue to increase it up to 1.8 – 4 °C by the end of 21st century (IPCC, 2007). Observed warming over several decades has been linked to change in ecosystem water balances such as altered precipitation and evaporation pattern (Cooter *et al.*, 2000; IPCC, 2007; Rambal and Debussche, 1995). Co-occurring altered precipitation patterns will likely lead to extended periods of water limitation or even drought, especially for vegetation on shallow soils with low soil water storage capacity (Gessler *et al.*, 2004). The resultant global warming and climate change exert increasingly the researchers around the world have generated an effort to understand how environmental changes, such as those seen in temperature and precipitation, influence on ecosystem carbon and water balance (e.g. Aires *et al.*, 2008b; Anthoni *et al.*, 2002; Fu *et al.*, 2006; Law *et al.*, 2002).

Drought effects on ecosystem carbon and water balance are important to study from two practical perspectives (Reichstein *et al.*, 2002b). First, direct and indirect effects of drought on ecosystem function and stability are major concern for policy and economy, and high costs are anticipated for its mitigation (Watson *et al.*, 1995). Secondly, ecosystems are considered an important regulator of global climate, mainly providing a feedback concerning emissions of greenhouse gas CO_2. Thus, for predicting climate change it is important to know if ecosystems will be sink or source of CO_2.

Agriculture claims about one third of the global land area and is a main contributor to anthropogenic induced emission of greenhouse gases. It is accounts for 25% of carbon dioxide, 50% of methane and 70% of nitrous oxide emissions (Hutchinson *et al.*, 2007). The Kyoto protocol of the United Nations Framework Convention on Climate Change (UNFCCC) has risen the interest in the potential of agroecosystems to sequester carbon and thus, to substantially mitigate global warming impacts (Vleeshouwers and Verhagen, 2002). Climate change affects carbon storage in these ecosystems since both photosynthetic uptake of carbon and loss of carbon through respiration of plant and soils are depend on temperature, moisture, and radiation (Aubinet *et al.*, 2009; Moureaux *et al.*, 2006; Saito *et al.*, 2005). Since reasons for the net carbon uptake are not fully understood, it is difficult to make reliable projections of how agroecosystems will respond to the ongoing climate change. It is therefore of great importance to increase the knowledge of the biogeophysical and biogeochemical processes in these ecosystems.

State of current research

Peanut (*Arachis hypogaea* L.) is one of the important oilseed crop in world as its seed contains 44-56% oil and 22-30% protein on a dry seed basic (Savage and Keenan, 1994). In many parts of the world, peanut is grown under rainfed conditions. In this environment, peanut plants have to cope with unfavorable environmental factors such as high temperature, low soil moisture, and high vapor pressure deficit (*VPD*), often resulting in drought stress. Drought affects nearly all aspects of plant growth and most physiological processes; however, the stress response depends on the intensity, rate, and duration of exposure and the stage of crop growth. Inconsistent effects of these environmental stresses on physiological depression have been reported in previous studies (e.g. Bhagsari *et al.*, 1976; Lauriano *et al.*, 2004; Nautiyal *et al.*, 1995; review by Reddy *et al.*, 2003b). Measurements made in most studies were conducted at ‘leaf scale”. There is still a lack of information on a continuous basis of the effects of drought stress on carbon and water vapor exchange at the canopy scale. To this end, the preferred technique is the eddy-covariance (EC) method (Aubinet *et al.*, 2000; Baldocchi, 2003), which allows to measure spatially integrated carbon and water vapor exchange on a continuous basis with minimal disturbance to the crop.

With these continuous measurements the derivation of annual sums of net ecosystem CO_2 exchange (*NEE*) or the integration over a vegetation period became possible. However, missing values or gaps resulted from instrument failure, system maintenance, precipitation, inadequate turbulence, and various other rejection criteria in these flux records are unavoidable (Papale *et al.*, 2006). Data gaps in time series present challenges for researchers, as imputation of missing values (i.e., “gap filling”) is a prerequisite to estimating daily and annual sums of *NEE* (Falge *et al.*, 2001b), or any other quantity for which a temporal integral is desired. *NEE* sums are of special interest to the global change research community because scaling site-level carbon balance information to regions and continents contributes to improved models and understanding of the global carbon cycle (Wofsy and Harriss, 2002). Particularly, gap-filling techniques are based on a range of approaches. Very common is the use of a regression analysis of *NEE* with key environmental factors like photosynthetic active radiation for daytime assimilation (e.g. a Michaelis-Menten function cited by Falge *et al.* (2001a)) or soil/air temperature for nighttime respiration (e.g. Lloyd and Taylor (1994)). Since the components of *NEE* such as photosynthesis and respiration often depend upon more than one factor, the regression base on one factor response functions of components to their drivers may not appropriate, especially in water-limited ecosystems (Holst *et al.*, 2008; Li *et al.*, 2005; Serrano-Ortiz *et al.*, 2007; Wang *et al.*, 2008). This due to the environmental stresses resulting from drought depressed *NEE*. Although the limitation of using the regression analysis has been previously observed in various ecosystem (Holst *et al.*, 2008; Li *et al.*, 2005; Serrano-Ortiz *et al.*, 2007; Wang *et al.*, 2008), to date a mechanistic explanation of this limitation is still missing. In order to develop improved models to reliably predict the long-term *NEE* and estimate their contribution to the global carbon cycle, the studies of the extreme environmental conditions such as drought on *NEE* are needed.

Over two-thirds of terrestrial carbon is stored belowground and significant amount of the atmospheric CO_2 fixed by plants is respired by roots and microbes in terrestrial soils, so soil respiration or soil CO_2 efflux is a key process driving the terrestrial carbon cycle (Ekblad *et al.*, 2005; Hibbard *et al.*, 2005). As stated-above, an increase in atmospheric CO_2 concentrations has been identified as the main cause of currents global warming (IPCC, 2007). Given the magnitude of soil respiration fluxes, relatively small changes at the global scale can signify large changes in the amount of carbon stored in soils and in the atmosphere. A release of carbon from soils through respiration following climate change would create a positive feedback mechanism exacerbating warming effects. Conversely, increased storage of carbon in soils would imply a negative feedback and diminished warming effects. Soil temperature and soil moisture content are principal driving variables for soil CO_2 efflux at the global scale (e.g. Boone *et al*., 1998; Davidson *et al*., 1998; Jassal *et al*., 2008; Riveros-Iregui *et al*., 2007; Vargas and Allen, 2008c). More attentions have been paid on the factors associated with changing climate, including temperature and precipitation, which control soil respiration and would affect exchange of carbon between terrestrial ecosystems and the atmosphere (Davidson *et al.*, 1998).

Rates of soil CO_2 efflux are currently estimated from a wide range of ecosystems with manual soil respiration chambers (Fang and Moncrieff, 1996; Subke and Tenhunen, 2004; Welsch and Hornberger, 2004), automated soil respiration chambers (Goulden and Crill, 1997; Savage and Davidson, 2001; Shi *et al.*, 2009), and the soil CO_2 gradient methods (e.g. Hirano *et al.*, 2003; Hirsch *et al.*, 2004; Jassal *et al.*, 2004; Riveros-Iregui *et al.*, 2008; Riveros-Iregui *et al.*, 2007; Tang *et al.*, 2005b; Tang *et al.*, 2003; Turcu *et al.*, 2005; Vargas and Allen, 2008a; Vargas and Allen, 2008b; Vargas and Allen, 2008c). Particularly in recently, the soil CO_2 gradient method has gained popularity because it can provide continuous and automated measurements at temporal scales useful for comparison with other techniques of ecosystem carbon exchange such as eddy-covariance towers (Baldocchi *et al.*, 2006) The soil CO_2 gradient method uses Fick's first law to calculate soil CO_2 efflux, and relies on both measurements of soil CO_2 profile and on the CO_2 diffusion coefficient in the soil (D_s) (Davidson and Trumbore, 1995). In practice, it is difficult to accurately estimate D_s with either models or experimentally, and this limitation constitutes one of the main sources of error associated within the gradient method (Liang *et al.*, 2004). Further studying on the soil CO_2 gradient methods to accurate measurements of soil respiration are thus needed.

Study Objectives

The overall goal of the work described in this thesis is to quantify the effects of drought on carbon dioxide (CO_2) and water vapor (H_2O) exchanges and soil respiration in peanut field. To accomplish this goal, the eddy-covariance method and the soil CO_2 gradient technique were established to measure CO_2 and H_2O exchanges and soil respiration, respectively. The specific objectives are:

- To examine the variation of daytime *NEE* (CO_2 flux), ecosystem evapotranspiration (E), surface conductance (g_s), ecosystem water use efficiency (*EWUE*), energy flux such as latent heat flux (λE) and sensible heat flux (H), and relevant environmental factors in relation to drought stress.

- To illustrate the underlying physiological mechanism of depression of CO_2 and H_2O fluxes.
- To explain the inability of using the Michaelis-Menten equation to describe *NEE-PAR* relationship.
- Compare efficiency of using soil CO_2 gradient method soil to measure soil CO_2 efflux against soil respiration chamber.
- To examine the responses of soil CO_2 efflux to drying and rapid rewetting of soil.
- To determine the effect of drying and rapid rewetting of soil on the sensitivity of soil CO_2 efflux to soil temperature and soil water content.