Abstract

Plant development is inherently linked to meteorological variability. The phenology, distribution and production of crops and wild relatives has already altered in response to climate change. Recent years have produced the warmest mean annual global temperatures since 1880, with 2016 setting the highest record thus far. Such profound changes have sparked investigations into the impact of temperature and rainfall on crop development, particularly those with profound economic importance such as coffee (*C. arabica*). The crop is a fundamental source of income for smallholder farming communities and governments throughout the tropical highlands. However, the impact of climate change on *C. arabica* has yet to be quantified using empirical data in East Africa, leaving uncertainty in the cultivable future of the crop. Therefore, the objective of this thesis is to investigate the influence of climate change and variability on *C. arabica* yields and phenology in East Africa.

Using a spatio-temporal approach, trends and relationships between coffee performance and meteorological variables were analysed at different scales and time periods ranging from the macroclimatic national scale (49 year), to the meso- and microclimatic farm level (3 year) scale, and finally to the microclimatic canopy and leaf level (hourly) scales. Data from all three climatic continua reveal for the first time that temperatures, and particularly rapidly advancing night time temperatures, are having a substantial negative impact on *C. arabica* yields. Forecasting models based on these biophysical relationships indicate that by the year 2050, smallholder farmers would on average harvest approximately 50% of the yield they are achieving today. Warming night time temperatures are also responsible for advancing ripening and harvest phenology. As a result, bean filling and development time is reduced, thereby potentially resulting in lower quality coffee. Trends in precipitation do not appear to have any substantial impact on *C. arabica* yields or harvest phenology, however, it is proposed that rainfall would act synergistically with temperatures to influence plant development and other phenological phases such as flowering. Finally, thermography is introduced as a novel complementary technique to rapidly analyse the suitability of different agroecological systems on coffee physiology at the leaf level. High temporal resolution (hourly) data, illustrate the success of the method in variable meteorological and environmental conditions. The findings contribute to advancing the protocol for use at the canopy and plantation

level on coffee, so that appropriate microenvironment designs and adaptation mechanisms be put in place to accommodate climatic change.

Avoiding increments in night time temperatures is key to maintaining or improving yields and fruiting development. Farming at higher altitudes and novel agroforestry systems may assist in achieving lower night time temperatures. Importantly, data reveal that careful analysis of various cropping systems, particularly at lower altitudes, is critical for providing suitable microenvironments for the crop.