AC0310 **Annex 1**

Impact of climate change on grassland

Introduction

Grassland accounts for 70% of the UK agricultural land and approximately 32% of agricultural output (IGER, 2003). Increased concentrations of atmospheric CO_2 and changes in climate in the future are likely to have an impact on grassland and production of grazing animals. Effects might include changes in the grazing season, yield, species and nutrient composition.

Impact of climate change

The UKCP09 future weather projections suggest overall warming accompanied by wetter winters and dryer summers (Jenkins et al., 2009). Grassland is sensitive to drought (MAFF, 2000) and dryer summers in the future might place limitations on grass growth on soils with low soil available water in the summer months (St. Claire et al., 2009). More drought resistant species might be required to meet livestock grazing needs or increased costs associated with additional feeding might occur. Drought will also increase the risk of wildfires affecting extensive grazing areas. Wetter winters may cause water logging and problems of poaching, possibly resulting in animal having to be housed, and reduced opportunities for grazing and harvesting (Hopkins and Del Prado, 2007). Good soil structure to promote resilience to the effects of drought and water logging should be encouraged (IGER, 2004). Draining water logged soil would encourage early grass growth, but at the expense of a reduction in water availability in July and August (Armstrong and Castle, 1992).

Temperature rise is likely to increase the length of the grazing season (Topp and Doyle, 1996a; IGER, 2003) with grass production starting earlier in the spring and continuing later into the autumn. This could have advantages for availability of grass during early lambing. Although the rate of photorespiration increases with temperature (Nowak et al., 2004), potential for increased herbage will be limited by nitrogen availability and in some areas irrigation during dry months and drainage during wet months (IGER, 2004). The longer growing season may result in increased grassland yield (ADAS, 1997) though other models suggest that the longer growing season might only increase clover production and have little effect on yield overall after the impact of drought is taken into account (Topp and Doyle, 1996a; Grime et al., 2008).

Impact of increased atmospheric CO_2 concentrations

There is consensus that increased atmospheric CO_2 concentration increases the rate of photosynthetic CO_2 assimilation while decreasing stomatal conductance (for reviews see

(Nowak et al., 2004; Soussana and Luscher, 2007). Overall this is likely to increase grassland yield under future elevated atmospheric CO_2 concentrations. Experiments where atmospheric CO_2 concentration is enriched to levels predicted in the future, known as Free Air CO_2 Enrichment (FACE), indicate on a frequently cut sward yield might increase by 56% with increased temperature and atmospheric CO_2 concentration compared with an ambient baseline (IGER, 2003). While nitrogen (N) availability has no direct effect on photo-synthetic rates, N availability is frequently a limiting resource for plant growth (Aeschlimann et al., 2005). Thus adaptation in the future might involve increased use of legumes with ability to fix nitrogen. In fertile grasslands legumes benefit more from elevated atmospheric CO_2 concentrations than non fixing species (Luscher et al 1998). However, legumes might be limited from responding to atmospheric conditions by a lack of other nutrients such as phosphorus. Increased atmospheric CO_2 levels might also help grass to survive in droughty conditions when stomatal conductance is reduced (Soussana and Luscher, 2007); although (Nowak et al., 2004) reported FACE data provide only limited support for this assumption. The response of grasslands to elevated atmospheric CO_2 concentrations over the longer term did not vary across 10 years of experiment data (Ainsworth et al., 2003).

Impact of climate change and atmospheric CO_2 concentrations on species composition

Changes in temperature, rainfall and atmospheric CO_2 concentration might affect different forage species in different ways therefore altering the species composition of the grassland community. Overall conditions are likely to become more favourable for forage legumes (Soussana and Luscher, 2007). Management factors such as frequency of defoliation, will also be important in determining how species diverse communities respond to changes in climate and atmospheric CO_2 concentration (Teyssonneyre et al., 2002; Harmens et al., 2004). C_3-grasses, that have higher protein content than C_4-grasses and may therefore have higher nutritional value, will have increased competitive advantage over C_4-grasses under conditions of elevated atmospheric CO_2 concentration (Ehleringer et al., 2002; Soussana and Luscher, 2007). However, the projected increase in temperature will favour C_4-species (Soussana and Luscher, 2007) therefore the outcome remains difficult to predict. In general, species-rich grasslands are likely to be more productive in response to elevated levels of atmospheric CO_2 concentration than species-poor grasslands (Reich et al., 2001).

Impact of climate change and atmospheric CO_2 concentrations on grassland nutrition

The main factors that determine the nutritional quality of grassland are; dry matter content, digestibility, energy and protein (HCC, 2008). The protein provided by forage is related to the nitrogen content (Rinehart, 2008) and elevated atmospheric CO_2 concentrations have been shown to be associated with reduced shoot nitrogen (Soussana et al., 1996; Ehleringer et al., 2002; IGER, 2003), as well as reduced vitamins (Soussana et al., 1996) and increased soluble carbohydrate (Ehleringer et al., 2002; IGER, 2003). Age of the plant also affects the nutritional content of forage. Older plants have less protein, lower digestibility and more fibre (NationalResearchCouncil, 1985; Rinehart, 2008). Therefore increased growth rate associated with increased atmospheric CO_2 concentration, which might allow younger plants to be consumed, might help increase the protein and the soluble carbohydrates content for livestock (Rinehart, 2008). Although the exact impact of climate change on grassland nutrient content remains unclear, there are some indications that reduced protein in grazing might impact negatively on weight gain in cattle (Owensby et al 1996 in (Topp and Doyle, 1996b; Ehleringer et al., 2002; Craine et al., 2009). Published studies of the impact of climate change on nutrition of grazing sheep appear lacking to date. As stated by (Campbell et al., 2000), forage quality in the future could decline in systems where feed conversion efficiency is limited by protein and might increase or remain unchanged in systems where it is limited by carbohydrate availability

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