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IMPACTS OF CLIMATE CHANGE ON ANIMAL FEED SOURCES

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INTRODUCTION

The impacts of climate change on agriculture come about through changes in variability, seasonal patterns of solar radiation and rainfall, temperature, air humidity, atmospheric carbon dioxide (CO_2) concentration and soil conditions (Rotter & Van de Geijn 1999). These changes interact with agriculture through various directs and indirect processes. Each of these mechanisms is likely to become more significant with higher rising temperatures, and clearly the overall impacts of climate change in agriculture. According to the Intergovernmental Panel on Climate Change (2007), global mean temperature is likely to rise by approximately 1.4-5.8ºC by 2100. Such change will have direct impacts on crop yields, pasture production and vegetation through high temperature, indirect impacts associated with precipitation changes, and the elevated concentration of atmospheric CO_2.

It is widely known that the climate change affect livestock production through four main ways: through changes in livestock grain feed and price; impact on livestock pastures and forage crop production and quality; the direct effects of weather and extreme events on animal health, growth and reproduction; and changes in the distribution of livestock diseases and pests (Rotter and Van de Geijn 1999). In which, pasture, forage crop production and quality can be considered as one of the most vulnerable sector, because it seems that these impact directly on quantity and quality of animal feed sources that contribute considerably to the development of livestock production, and associate with animal and human food security, subsequently.

It is clear that all such changes have significant impacts on pastures and forest production. This paper reviews some effects of climate change on pastures and forage crop production as results of changes in temperature, rainfall or water availability, soil environment, and level of atmospheric CO_2 concentration. Then, it is important to consider mitigation and adaptation methods in order to alleviate the impacts of climate change on this sector.

Effects of CO_2 concentration on plant growth, pasture, forage yield

Changes in atmospheric gas composition can influence plant-animal interactions in fundamentally different ways which affect plant metabolism, the quality of leaves, and forage biomass volume as a resource for livestock (James et al. 2002). It is no doubt that changes in atmospheric CO_2 will affect animal feed quality by influences in protein content, soluble carbohydrate content, fiber content, and the abundance of different secondary compounds. Most of recent studies have concluded that higher levels of CO_2 concentration increased plant biomass and yield (Kimball 1983; Kimball et al. 1993; Poorter 1993; Wand et al. 1999; James et al. 2002; Nowak et al. 2004; Parry et al. 2004 and Tubiello et al. 2007). It is because the high level of CO_2 stimulates the photosynthesis in plants, leading to the increased plant productivity and modified water and nutrient cycles (Kimball et al. 2002). Poorter (1993) reported that doubling elevated CO_2 concentration in atmospheric accelerated an average of

37% to plant growth rate. Similarly, Parry et al. (2004) illustrated that a 30 - 50% leaf photosynthesis increase in C3 plant species, and a 10 - 25% in C4 species were observed when the level of CO_2 concentration doubled in the air. Gifford (2003) reported that at the CO_2 concentration of 550 ppm, the yield increased by 10-20% in C3, and by 0 - 10% in C4 crops as compared with the yield at the current atmospheric of appropriate 380 ppm CO_2 concentration.

However, this positive effect of CO_2 concentration is found substantially in C3 species, yet little in C4 (Kimball et al., 2002). Moreover, it decreases stomatal conductance in both C3 and C4 species and greatly improves water-use efficiency in all crops. Growth stimulations are larger under water stress as compared to well-watered conditions. At low soil nitrogen, stimulations of non-legumes are reduced, whereas elevated CO_2 strongly stimulates the growth of the clover legume (Kimball et al., 2002).

Interestingly, Parry et al. (2004) estimated that climate change may result in crop yield decreases in developing countries and yield increase in the developed countries. According to the estimation, decreases are especially significant in Africa and a part of Asia with expected losses up to 30%. By 2080s, effects of elevated CO_2 levels on cereal and maize yield in Africa are projected to reduce by as much as 20% and 30% respectively. In North America, South East Asia, South America, and Australia, the effects of CO_2 on the crops partially compensate for the stress conditions imposed on the crops and result in smaller yield increases. The coolest climate change scenario results in smaller cereal yield decreases that never exceed 10% (Parry et al., 2004). This means that feed resources, particularly grains or cereals will become a great challenge for the future livestock production.

Moreover, if assuming no CO_2 effects, cereal yields will fall by as much as 10% throughout Eastern Europe and parts of Africa, primarily as a result of the impact of increased temperature (Parry et al., 2004). Parry et al. (2004) projected that major areas of maize production will be reduced by up to 18%, and rice production will be also reduced around 10% by 2050s. Furthermore, wheat and barley yields will be also reduced by as much as 20% throughout Africa and Latin America, while cereal yield worldwide will be depressed by, on average, 10% by 2080s. Also, at the meantime, the maize yield of the northern hemisphere, where temperatures are, on average, 2^oC cooler, will be depressed by no more than 10%.

While the elevated CO_2 concentration may have positive effects on plant growth in experiments, the results of plot level experiments are likely to overestimate the reality of the CO_2 effects because of complicating factors which occur in the real world and not in the experiments, such as pests and weeds, lack of competition for other necessary resources, and extreme events. These interactions are neither well understood at large scales nor well implemented in leading models.

Several researches have indicated that CO_2 concentration affects plant growth significantly together with others environmental variables such as temperature, precipitation, nitrogen, and air pollutants (Rotter and Van de Geijn, 1999; Tubiello et al., 2007). Although an increase in CO_2 concentration is demonstrated to increasing the plant growth and productivity, these effects will often be countered in reality by other changes in the system (Tubuiello et al. 2007). In fact, higher temperatures during certain growth stages may be detrimental to yield and quality (Caldwell, 2003; Vara Prasad et al., 2003; Baker, 2004). Increased plant growth caused by elevated CO_2 may lead to a greater water demand (Xiao et al., 2005), which in many parts of the world may be combined with a increasing pressure on water resources, which may also be declining, and hence become a limiting factor.

In pastures, elevated CO_2 combines with increases in temperature and precipitation resulted in an increased primary production, with changes in species distribution and litter composition (Zavaleta et al., 2003 and Henry et al., 2005). Tubiello et al. (2007) suggested that the increase in future CO_2 levels may favour C_3 plants over C_4; however, it seems that the opposite trend is expected to associate with the temperature increase. Similarly, the availability of soil nutrients such as nitrogen and phosphorus may also be limiting factors to the CO_2 response.

Parry et al. (2004) stated that most of agricultural plants increase the growth rate and yields in the environment of higher elevated CO_2. However, the higher ambient CO_2 will also ultimately translate into changing climatic parameters. Potential CO_2 effects on plant biomass depend on the availability of water and nutrients. Hence, the positive impacts of elevated CO_2 can only be realised if other parameters of biological productivity are not limited.

Effects of changes in rainfall on pasture systems

Global climate change is predicted to alter rainfall patterns, potentially reducing total amounts of growing season precipitation and redistributing rainfall into fewer but larger individual events (Fiala et al., 2009). Tao et al. (2003) reported the results of a macro-scale water balance model, which predicted that in the years 2021–2030, water demand will increase world-wide due to the climate change. If the temperature and rainfall conditions change more rapidly than the change in CO_2 then the consequences could be much more serious (Lawlor, 1998). Moreover, Fiala et al. (2009) conducted a study to examine effect of rainfall on root production and plant belowground dry mass of different grassland ecosystem in three climate scenarios (rainfall reduced by 50%, rainfall enhanced by 50%, and the full natural rainfall of growing season). Thay concluded that differences in water availability were reflected not only in root growth but also in total below ground biomass accumulation. Furthermore, reduction in precipitation resulted in a significantly lower accumulation of roots and total belowground biomass in dry than wet seasons in the highland grassland (Fiala et al., 2009).

It can be noted that climate change may affect ecosystem functioning through increased temperature or changes in precipitation patterns. In fact, temperature and altered water availability are important drivers for ecosystem processes, such as photosynthesis, carbon translocation, and organic matter decomposition. Reduced amounts of rainfall and drought mostly restrict aboveground plant growth (Oomes & Mooi, 1981; Pandey & Singh, 1992; Silvertown et al., 1994; Lane et al., 2000).

Furthermore, Hui & Jackson (2006) concluded from a large collection of field biomass measurements that the proportion of belowground net biomass production in total net primary production was negatively correlated with means of annual temperature and precipitation across sites. Decreased soil moisture and drought reduced decomposition processes of dead plant matter in many ecosystems (van Oorschot 2000). In addition, gradual temperature change, in conjunction with elevated CO_2 levels, is expected to increase grassland productivity in general, with the greatest positive effect expected at high latitudes (Henry et al. 2005). However, projected decreases in rainfall in some major grassland and rangeland areas may have important implications for productivity and plant species composition. Reduced rainfall may cause groundnut yields to reduce, while there may be large increases in cotton yields (C3) due to increases in ambient CO_2 concentration. However, changes in temperature and precipitation may negate these effects (Craufurd & Wheeler 2003).

Drought is a typical phenomenon of climate changes related to reduction of rainfall, which affects adversely on the pastures and forage yield. Esther et al. (1998) illustrated that drought affects N2-fixation as well as root growth. Experiments on soybean conducted by the authors showed that water reduction can bring about a marked limitation in the yield of soybean by impairing N2- fixation as well as photosynthesis. The authors further indicated a significant correlation between sucrose synthesis activity and apparent nitrogenise activity, which suggests that a stress related decline in N2- fixation could well be caused by a reduction in sucrose flow to the nodule through the phloem.

Taylor et al. (2011) reported that under drought condition, stomatal conductance declined more dramatically in C3 than C4 species, and photosynthetic water-use and nitrogen use efficiency advantage held by C4 species under control conditions were each diminished by 40%. Leaf mortality was slightly higher in C4 than C3 grasses, but leaf condition under drought otherwise showed no dependence on photosynthetic types.

For cotton (C3 plant), a crop with a relatively large biomass response to elevated CO_2, Bhattacharya et al. (1994) found a little consistent effect on plant water potential by free-air carbon dioxide enrichment (FACE) except near the end of the season. Wheat has somewhat smaller biomass response than the cotton. Wall et al. (1994) reported that for most of the daylight, wheat leaves exposed to FACE at 550 μmol mol^{-1} had slightly, but statistically significant, less negative water potentials compared to ambient grown plants. However, sorghum, a C4 plant with a little growth response to FACE under ample water and nutrients, had a higher (less negative) average water potential of 2.8% (Wall et al., 1994). Under water stress, water potential improved relatively even more due to the elevated CO_2 by − 8.8%. On the other hand, grape, a woody C3 plant likes cotton, exhibited a slight improvement in water potential when it was well watered (Taylor et al., 2011).

Agronomic research indicates that a higher temperature associated with the climatic change will be harmful to the production of many crop and livestock groups. Where there is a water stress, heat stress or a combination of the two, the world's cereal crops can be vulnerable to even minor changes in temperature. The agronomy of all crops will be affected by both temperature and precipitation change and by the increased atmospheric concentration of carbon dioxide.

Effects of climate change on soil environment

The response of soils to climate will derive from changes in the rates of changes in physical, chemical or biologically-mediated, which will, ultimately, lead to changes in soil properties with fareaching implications (Rounsevell et al., 1999). It appears that soil properties will be influenced directly by temperature, precipitation, and atmospheric CO_2 changes, and indirectly by climate- induced changes in land use and management. In turn, changes in the soil will affect the composition and structure of pastures and crop and feedback to the climate system.

Firstly, the change in soil nutrient is one of the most important changes caused by climate change that affects adversely on crop and pasture yields. Indeed, plant growth and soil water use are strongly influenced by the availability of nutrients. Where climatic conditions are favourable for the plant growth, the shortage of soil nutritients will be very important

(Rounsevell et al., 1999). It is noted that increased plant growth in a CO_2 enriched atmosphere may rapidly deplete soil nutrients and consequently the positive effect of CO_2 increase may not persist as soil fertility decreases (Bhattacharya et al., 1994). Moreover, the rising concentration of CO_2 in the atmosphere has the potential to alter many aspects of plant growth that in turn could result in changes in soil properties, such as storage of carbon, nitrogen, phosphorus, potassium and sulphur.

A large number of studies have demonstrated the direct effects of elevated CO_2 on the carbon balance of grassland species as a result of an increase in Nitrate Phosphate at elevated CO_2 and a preferential allocation of additional fixed C to the roots and subsequently to the soil. Exposure of grassland to elevated CO_2 concentration has been shown to affect soil aggregate size, but the response appears to be restricted to drier soils. Consequently, whereas Rillig et al. (1999) found elevated CO_2 increased aggregate size in two Mediterranean grassland systems, possibly because of increased mycorrhizal secretion of glomalin promoting soil aggregation.

Moreover, also in dry periods, microbial activity in soil may increase because of greater moisture content resulting from higher water-use efficiency of plants in response to elevated CO_2 (Williams et al. 2000). As a result of greater microbial activity, N availability may increase because of the more rapid recycling of microbial N. Hu et al. (2001) stated that elevated CO_2 reduces the amount of N available to microbes through the enhanced plant growth. This could result in an enhanced C accumulation in grassland soils at elevated CO_2.

Another impact of climate change on soil environment is that higher temperature environments lead to changes in soil water contents. This is due to the evapotranspiration process, and plant water use is further influenced by elevated atmospheric CO_2 concentrations (Rounsevell et al., 1999). Kirschbaum et al. (1996) reported that increasing atmospheric CO_2 concentrations will lead to lower stomatal conductance and increased leaf photosynthetic rate. This will improve water use efficiency, so that plants with limited soil water supply will fix more atmospheric carbon in the future than at present. However, the ability to fix carbon can be constrained by soil water shortage or drought, soil nutrient availability, temperature, humidity and vapour pressure, the authors further proposed. Furthermore, there is also increasing evidences on the capacity of plants to respond to elevated CO_2 concentrations through morphological adaptation, such as reducing the density of stomata (Woodward & Kelly 1995).

Additionally, a change in soil temperature is another effect of climate change on soil environment that may result in declines in crop and pasture production. It is clear that soil temperature is directly related to air temperatures, so that warmer soils will arise from the warmer earth, although the conductivity of heat through soil is mediated by the mineralogy, the organic matter content, soil moisture effects, the surface and the vegetation.

Effects of climate change on pasture structure (C3/C4 ratio)

Most important agricultural crops exhibit higher rates of photosynthesis with higher ambient CO_2. Pasture system change from C3 to C4, and C4 plants will become as major food resources. Indeed, Cerling et al. (1997) and Ehleringer et al (1997) modelled the fitness relationships between C3 and C4 taxa and demonstrated that at the same atmospheric CO_2 values, C3 plants are more favoured in cooler climates, while C4 plants in warmer climates.

Moreover, many studies have compared the responses of plants with C3 and C4 photosynthetic pathways to atmospheric elevated CO_2 (Poorter 1993; Dippery et al., 1995;

Wand et al., 1999 and Taylor et al., 2011). While some proposed that C3 species show enhanced net photosynthesis and growth with the elevated CO_2 (Ceulemans & Mousseau, 1994 and Curtis, 1996), others illustrated that C4 species are generally less affected by te increasing elevated CO_2 concentration because of a lower CO_2-saturation point for photosynthesis (Sage 1994, 1995). Ward et al. (1999), however, predicted that C3 species may have a competitive advantage over C4 species in the future as atmospheric elevated CO_2 continue to rise. Ward et al. (1999) further proposed that environment stresses generally reduce the response of C3, but not C4. Therefore, C4 plants likely maintain their competitive advantage over C3 plants in CO_2 enrichment environments.

Furthermore, several studies demonstrated that effects of elevated CO_2 concentration on C3 and C4 in mono-cultures were different. Wand et al. (1999) and Pooter et al. (1999) concluded that elevated CO_2 has enhanced biomass in C3 by 41- 44%, which was higher than that in C4 plants (22-33%). Interestingly, Mooney et al. (1999) and Campbell et al. (2000) reported that doubling ambient CO_2 has increased production of C3/C4 mixed-plant communities by only one-half (14-17%) of that generally reported for the component mono- cultures. However, CO_2 enrichment increased production of a C3/C4 community in the short-grass steppe by 26-47% during years with above average annual precipitation (Morgan et al., 2004).

Derner et al. (2003) conducted a study to measure above-and below-ground responses of cotton (C3) and sorghum (C4) plants in mono-cultures and mixtures and concluded that CO_2 enrichment and soil water influenced growth of C3 and C4 plants in monocultures and mixtures. According to the study, CO_2 enrichment increased C3 plant growth in both monocultures and mixtures, while growth responses of the C4 plant with CO_2 enrichment were reduced in mixtures compared to monocultures. Elevated CO_2 enhanced 84- 86% leaf area and above-ground biomass of individual C3, but not C4 (-2 to 6%) plants in monocultures (Derner et al., 2003).

Regarding to interaction between CO_2 enrichment and soil water on growth of C3 and C4, there is opposite statements. Hunt et al. (1996) and Ward et al. (1999) proposed that CO_2 effects depend on soil water availability, while Derner et al. (2003) concluded that effects of CO_2 did not depend on soil water treatment for above- or below-ground variables for either C3 (cotton) or C4 (sorghum) plants.

Grassland management to mitigate effects of climate changes on pasture and forage crop production

Mitigation of greenhouse gases that have significant impacts on pasture and forage production plays an important role not only for development of livestock production, but also for sustainable developments. Carbon dioxide is one of the certain greenhouse gases that affects significantly on the pasture. This gas is formed naturally in grassland systems through respiration (below-ground soil, shoot plants and herbivores) and is fixed into carbohydrates via photosynthesis. Grassland are generally regarded as potential sinks for CO_2 although soil management factors such as the frequency of ploughing and reseeding might alter the potential for carbon sequestration (Hopkins & Del Prado, 2007).

Another management factor may also affect the whole carbon balance of a farm, including emissions from farm machinery, and indirect CO_2 emissions associated with fertilizer manufacturing, transport of feed and other inputs to the farm. Also, the issue of the carbon balance of the whole farming and food supply business, including the fuel consumption of food chains and connectivity between the farm and the consumer.

For N_2O, this gas can be reduced by implementing practices aimed at enhancing the ability of the sward to compete with processes that lead to the escape of N from the soil-plant system (Freney, 1997). For instance, there are several methods for increasing the efficiency of the herbage of the sward to remove mineral N from the soil. These include increasing fertilizer-use efficiency (Brown et al., 2005), optimizing methods and timing of applications of fertilizer (Dosch & Gutser, 1996), using ammonium-based fertilizers rather than nitrate-based ones and employing chemical inhibitors of nitrification (Macadam et al., 2003).

Increasing soil aeration may significantly reduce N_2O emissions. Improving drainage could be particularly beneficial on grazed grassland (Monteny et al., 2006). Hence, avoiding compaction by traffic, tillage and grazing livestock may help reduce N_2O emissions. Housing system and management will also influence N_2O emissions, e.g. straw-based manures result in greater N_2O emissions than slurry-based ones (Groenestein & Van Faassen, 1996). Minimizing the grazing period is likely to reduce N_2O emissions as long as the slurry produced during the housing period is uniformly spread.

CONCLUSION

It is clear that the effects of climate changes on livestock feed sources are urgent issues. Although, elevated CO_2 concentration may enhance crop yield, most of changes in climatic conditions such as higher temperature, changes in rainfall and soil environment tend to have an adverse effect on pastures and forage yield, quality of food. In the future, perhaps, the most visible changes can be seen is that C4 plants will dominate C3 species. This change will bring about significant challenges in animal feed production. It is suggested that mitigation methods in order to minimize effects of climate change on pasture and forage production in terms of grassland management should be considered.

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