# Agricultural Systems for Saline Soil: The Potential Role of Livestock*

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**ABSTRACT :** Human-induced soil salinity is becoming a major threat to agriculture across the world. This salinisation occurs in both irrigated and rain-fed agricultural zones with the highest proportions in the arid and semi-arid environments. Livestock can play an important role in the management and rehabilitation of this land. There are a range of plants that grow in saline soils and these have been used as animal feed. In many situations, animal production has been poor as a result of low edible biomass production, low nutritive value, depressed appetite, or a reduction in efficiency of energy use. Feeding systems are proposed that maximise the feeding value of plants growing on saline land and integrate their use with other feed resources available within mixed livestock and crop farming systems. Salt-tolerant pastures, particularly the chenopod shrubs, have moderate digestible energy and high crude protein. For this reason they represent a good supplement for poor quality pastures and crop residues. The use of salt-tolerant pasture systems not only provides feed for livestock but also may act as a bio-drain to lower saline water tables and improve the soil for growth of alternative less salt tolerant plants. In the longer term there are opportunities to identify and select more appropriate plants and animals for saline agriculture. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 2 : 296-300)***

**Key Words :** Ruminants, Salinity, Chenopod, Nutritive Value, Sodium Chloride, Feed Intake

## INTRODUCTION

Humans rely on livestock for food and fibre and, in some locations, draught power, transport and fertiliser. Delgado et al. (1999) predicted the next 15 years will be part of a "Livestock Revolution", with a growth in the consumption of meat and milk of around 3% per year in developing countries. To meet this demand much more efficient animal production in rain-fed regions will be necessary, small ruminants in particular have the potential for increased production across a range of agro-ecological zones (Devendra, 2001). Currently the productive rain-fed mixed farming systems, that utilise both crops and livestock, are a major component of the agricultural economy in Asia and Australasia (Devendra and Thomas, 2002). While grazing livestock have received much attention as the cause of environmental damage in many areas (El Aich and Waterhouse, 1999), the prolonged use of annual crops in place of perennial vegetation and the increased intensity of land use for cropping have also been identified as contributing to land degradation and, in particular, the increase in dryland salinity (Ghassemi et al., 1995). In fact, increased use of land for cropping will, in some cases, result in a dual negative impact. In the smaller areas available for grazing, there will be an increase in soil erosion and reduction in plant biodiversity (Grime, 1973), biomass, soil fertility, and water infiltration associated with overgrazing. While, in the cropped areas, the replacement of perennial plants with annual crops can result in increased waterlogging and salinity in valley floors as a result of decreased year round water use (Hatton and Nulsen, 1999).

Human-induced salinity poses a major threat in both irrigated and non-irrigated agricultural systems in all continents of the world. FAO estimates are that at least 77 M ha of land are affected by human-induced salinisation and 33 M ha of this are in non-irrigated agricultural areas dependent on rain-fed agriculture (FAO/AGL-Global network on integrated soil management for sustainable use of salt-affected land, 2000). These figures are likely to be underestimates. Le Houérou (1992) claims there are 340 M ha of saline soils in the mediterranean climatic zones alone. The highest proportion of saline land is in Asia but the eastern Mediterranean, Africa, North and South America and Australia also face significant loss of agricultural land from salinisation. Where salinisation in rain-fed areas is associated with mixed farming systems that utilise crops and livestock for production, livestock may play an important role in the management and rehabilitation of land for production. This review addresses the role for livestock in the management of salinising landscapes.

## PLANT OPTIONS FOR SALINE LAND

A wide range of plant species have the potential to produce biomass for animal production, increase biodiversity and improve the visual amenity of saline land

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(Masters et al., 2001; Rogers et al., 2003; Barrett-Lennard et al., 2003). These options include plants that are tolerant to salt and waterlogging and plants that persist in saline areas by avoiding these stresses (eg through short lifecycles or shallow rooting). Perennial and annual species from the *Poaceae, Leguminaceae* and *Chenopodiaceae* families are currently planted in saline areas for livestock production. Some of these plants persist through accumulation of salt (e.g., halophytes) while others exclude salt at a high metabolic cost (e.g., many of the legumes).

Unlike conventional agricultural systems where monocultures of plants are often sown, the heterogeneity of saline environments is likely to require a range of plants to maximise biomass production. A recent study in Australia identified 35 different species growing on two highly saline sites (Norman et al., 2003). It was concluded that the high levels of plant diversity were related to the variability across the site and indicated that no one species was likely to dominate in all functional niches. These niches and complex interactions between plants (both competition and complementarity) need to be considered when evaluating options for saline land. In the short term at least, production of forages for animal production is more likely to yield an economic return than monocultures of conventional crops. Production of forage biomass is variable and will be a function of a range of factors including the level of salinity, waterlogging, soil texture and fertility, rainfall, method of establishment, interactions between plants and plant genotype (Barrett-Lennard et al., 2003).

Creation of saltland pasture systems that are environmentally sustainable, persistent and yield an economic return present a significant challenge to land managers.

## LIVESTOCK PRODUCTION FROM SALT TOLERANT PASTURES

### Field observations

There is little published information on the feeding value of salt tolerant pastures obtained from grazing experiments. Under moderate salinity plants such as puccinellia (*Puccinellia ciliata*), tall wheat grass (*Thinopyrum ponticum*), balansa clover (*Trifolium michelianum*) and sweet clover (*Melilotus alba*) will all produce good levels of biomass and, depending on grazing management, will support reasonable animal production (Warren et al., 1996; Thompson et al., 2001). With increasing salinity, plant systems tend to become more heterogeneous with a significant halophytic shrub component and a broad range of other plant species as “understorey”. The shrubs are usually from the *Chenopodiaceae* family and are widespread in the temperate, mediterranean, semi-arid and sub-tropical areas of the world. While chenopods have been advocated for animal feeding (Le Houérou, 1992; Gihad and El Shaer, 1994), results of grazing studies are often disappointing with grazing livestock either maintaining or losing weight (Morecombe et al., 1996). Despite these results, halophytic shrub-based pasture systems may still have a role in providing feed to ruminants during periods of seasonal shortages.

### Application of nutritional principles in the use of salt tolerant pastures

The poor production observed from ruminants grazing or browsing plants such as chenopods that accumulate salt is not surprising. In the first place, expected production is often overestimated through misinterpretation of dry matter digestibility (DMD) and crude protein (CP) measurements. Most of the chenopod shrubs contain high concentrations of salt (up to 30% of dry matter) and therefore, much of the apparently digestible material in these plants is salt and has no energy value. Using the textbook conversion of DMD to metabolisable energy, without correction for salt will give incorrect estimates of energy available for production. Crude proteins levels can also be misleading. These are usually calculated from nitrogen analysis and assume all nitrogen in the plants is in the form of protein. In reality, many salt tolerant plants contain high levels of non-protein-nitrogen, this nitrogen will only be available for conversion to microbial protein in the rumen if a good supply of metabolisable energy is available or if fed with protein deficient feed (Masters et al., 2001).

The consumption of salt will directly affect livestock production. The ability of livestock to tolerate high intakes of salt is dependant on the ability of the kidney to increase glomerular filtration rate and decrease salt reabsorption. For sodium, potassium and chloride, the animal has little or no capacity to store excess in the body or to actively excrete through the faeces. Acute excess of sodium has been associated with lower rectal temperature, raised pulse and respiration rates and water retention (Marai et al., 1995). Digestive function is also changed with an increase in the rate of passage of feed through the digestive tract, reduced concentrations of protozoa and selenomads in the rumen and decreased organic matter digestibility (Weston et al., 1970; Hemsley et al., 1975). High levels of sodium in the diet also depress appetite (Wilson, 1966) and the efficiency of energy use for production (Arieli et al., 1989). When these effects are considered together they cause a dramatic reduction in production. Figure 1 shows the depression in production when sodium chloride was added to a cereal hay/grain diet in penned sheep. Despite the composition of organic matter being identical for all treatments, growth decreased from 160 to 70 g/day as sodium chloride added to the diet increased from 0 to 20%.

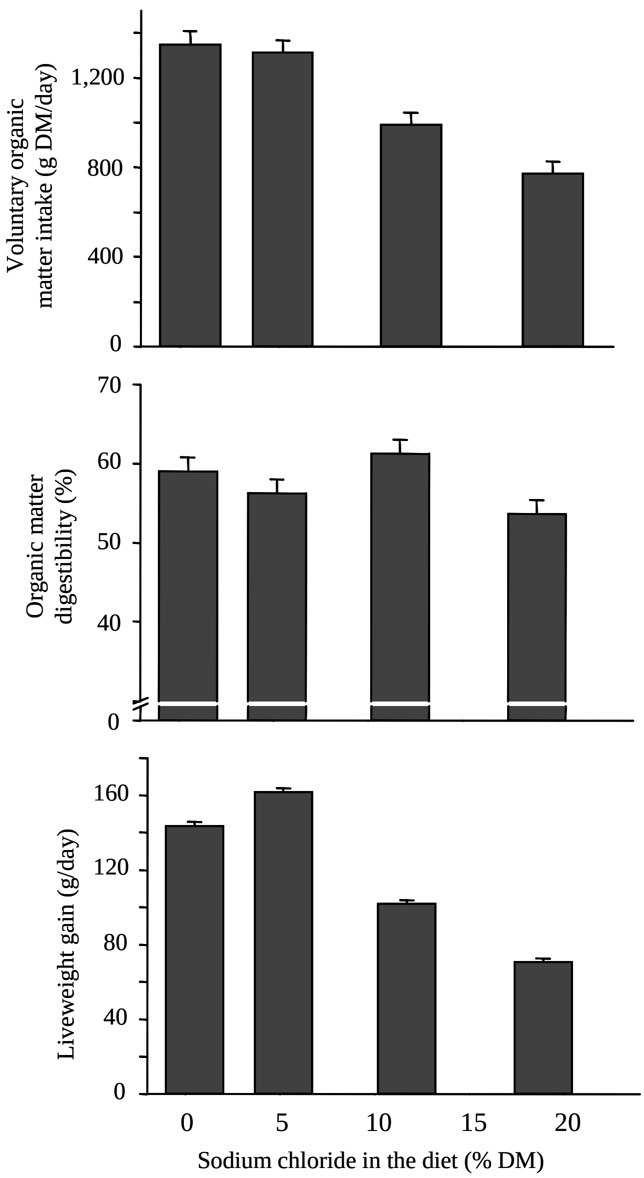


**Figure 1.** Changes in organic matter intake and digestibility and in liveweight gain when young sheep were fed a roughage based diet with added sodium chloride for 6 weeks (Masters et al., unpubl).

There are other nutritional considerations. A significant proportion of chenopod shrubs is indigestible wood, edible biomass may be a small proportion of total plant dry matter production. Also, it is not unusual for plants growing in saline areas to accumulate secondary compounds, either to discourage grazing or for use in osmotic regulation. These include betaine, oxalates, coumarins, tannins, nitrate and possibly other triterpenoids, steroids, glycosides, saponins and alkaloids (Masters et al., 2001). These can adversely affect palatability, feed intake and animal health.

More recently there is evidence that high levels of sodium chloride in the root zone influences the content of other minerals in the plant. Increasing sodium chloride in irrigation water has been shown to significantly reduce the

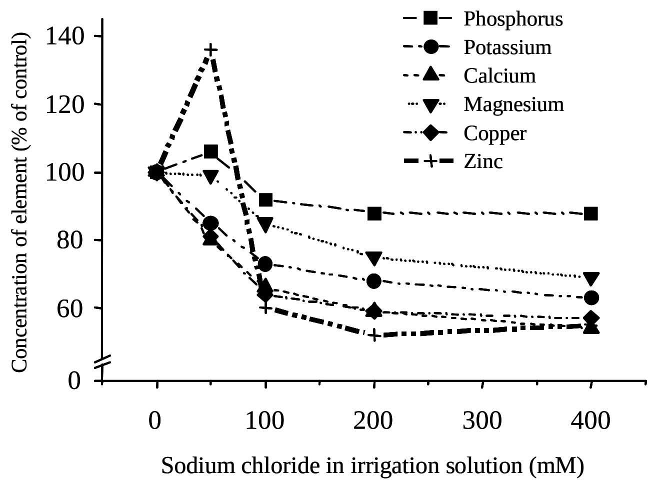


**Figure 2.** Reduction in mineral concentrations in growing river saltbush (*Atriplex amnicola*) with increasing concentrations of sodium chloride in the irrigation solution. (Tiong et al., unpubl).

concentrations of a range of elements in river saltbush (*Atriplex amnicola*) (Figure 2). These results, together with similar observations in non-halophytic plants grown at increased salinity levels (D. R. Revell pers comm.) indicate the possibility of specific mineral deficiencies or imbalances in grazing ruminants.

## DEVELOPING NOVEL SYSTEMS TO IMPROVE ANIMAL PRODUCTIVITY AND PROVIDE ENVIRONMENTAL BENEFITS ON SALINE LAND

### Increased animal production

Significant opportunities lie in the design and management of animal feeding systems that maximise the feeding value of plants growing on saline land and also integrate those plants with other available feed resources. This is a neglected area of research, with importance in both feed production for ruminants and stabilisation of salt-affected farmland. For example, providing a source of metabolisable energy to ruminants consuming chenopods with high levels of non-protein-nitrogen improves microbial crude protein production, liveweight gain and protein retention (Benjamin et al., 1992). Conversely, salt tolerant plants may improve the intake and utilisation of poor quality dry pastures or crop residues (Le Houérou, 1992; Warren and Casson, 1992; Nawaz and Hanjra, 1993; Chriyaa et al., 1997) and it may be that the greatest value of these shrubs is in the improvement in utilisation of low quality pasture (or understorey), crop residues or other shrubs, particularly in mixed farming enterprises. For example, in southern Sinai in Egypt, *Atriplex nummularia* and *Acacia saligna* are cultivated with the naturally occurring non-palatable species such as *Tamarix mannifera, Zygophyllum album* and *Halocnemum strobilaceum* to increase biomass utilisation by goats (El Shafer et al., 2000). Others have successfully used foliage from trees and shrubs as a replacement for more expensive protein supplements in diets based on poor quality roughage (Mui et al., 2002). To understand why these feeds are complementary requires consideration of the nutritive value of the feed components both separately and in combination. Most of the crop residues and dry pastures fed to ruminants have low organic matter digestibility (usually<50%) and crude protein (6-8%). Production is limited by low intake and poor utilisation of ingested material. The chenopod shrubs have reasonable organic matter digestibility (>60%) (Weston et al., 1970), even though the high salt levels mean they have low digestible organic matter in the dry matter, and high crude protein (7-20%) (Gihad and El Shaer, 1994). The high salt levels however restrict intake to maintenance or below (Casson and Warren, 1994). Currently vast quantities of low quality crop residues are produced in Australasia (Dann and Coombe, 1987; Devendra and Sevilla, 2002), and these are usually underutilised for animal production and in some cases are burned. Feeding systems that combine the shrubs with low quality pastures and crop residues are likely to result in increased organic matter and crude protein intake and improve digestibility.

### Environmental benefits of new animal production systems for saline areas

Given the apparent advantages of using the chenopod shrubs as a combined feed source with other complementary feedstuffs, there has been some attention on the ability of these shrubs to change salinity in the root zone and therefore improve the conditions for growth of other less tolerant plant species. The capacity of trees and shrubs to effectively act as bio-drains in saline areas is controversial (Clarke et al., 2002) but success has been reported in Australia, India and China (Bell et al., 1990; Chhabra and Thakur, 1998; Zhao et al., 2004). In a study to evaluate the water-use characteristics of old man saltbush (*Atriplex nummularia)* shrubs, Slavich et al. (1999), reported that there were low transpiration rates associated with the low leaf area index of the shrubs and suggested they were likely to have a low hydrological impact. In contrast, Ferdowsian et al. (2002) used a combination of water table observations and modelling to conclude that a plantation of *Atriplex* species lowered groundwater and prevented an increase in soil salinity at the surface. Consistent with these observations, others have reported that chenopod shrubs dry out the top 50-100 cm of soil and potentially decrease waterlogging and improve aeration at the top of the soil profile (R. Silberstein pers. comm.). These changes will increase the likelihood that shallow rooting annuals, that are less salt tolerant but have a higher nutritive value, will be able to grow and set seed.

## OPPORTUNITIES AND CONCLUSIONS

There are already options for the use of saline soils that provide a feed resource for grazing livestock. Revegetated saline soils used as part of a grazing system to complement other available feed resources indicates the potential for immediate benefits. Much more is possible. Most of the shrubs currently grown on saline soils are wild types; there has been some selection for improved ability to establish and persist but little for feeding value and performance under grazing. Similarly, there is evidence of genetic differences in salt tolerance both within and between animal species. Selection of more appropriate plants and animals, together with improved knowledge of agronomic and feeding management provides an opportunity to move from a low to a moderate productivity system. With appropriate management, this system will be profitable, sustainable and provide benefits in water use and biodiversity

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